THE QUEENSLAND CANE GROWERS' HANDBOOK

Stock

BUREAU OF SUGAR EXPERIMENT STATIONS
DEPARTMENT OF AGRICULTURE
BRISBANE

THE QUEENSLAND CANE GROWERS' HANDBOOK

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Preface

An attempt has been made to present the following chapters in logical sequence, and with the assistance of the detailed index, the farmer should have no difficulty in finding any subject in which he may be specially interested.

The chapters dealing with agricultural topics generally, have been prepared by the Director, Dr. H. W. Kerr, while the sections on Pest and Disease Control have been written by the Assistant Director, Mr. A. F. Bell. In each case, of course, members of the Bureau staff have been consulted in regard to their specialised knowledge, so that the publication must be regarded as the combined efforts of the staff, and not of the executive officers alone.

Constructive criticism or helpful suggestions are cordially invited, with a view to providing a more valuable Handbook if and when a further edition becomes necessary.

Foreword

The Bureau of Sugar Experiment Stations has issued, from time to time, a series of Bulletins dealing with various phases of cane cultivation, cane varieties, disease and pest control. In recent years, these have been supplemented by " The Cane Growers' Quarterly Bulletin," which has aimed at keeping the cane farmer informed on topical questions, and discussing in detail recent advances in our knowledge. But the presentation of " The Queensland Cane Growers' Handbook " marks the first attempt to place in the hands of the cane grower a comprehensive treatise on all major subjects which should interest him in the production and protection of his crop.

Much has been heard in recent times of the need for scientific agriculture; often the term is used glibly by individuals who do not adequately appreciate the true significance of the term. It does not mean that the farmer, to be successful, must have a profound scientific training, or be capable of understanding and discussing all the intricacies of the scientific processes taking place in the soil. Rather the " scientific " farmer is the " commonsense " farmer; the man who understands the principles which combine to provide those conditions most favourable for the production of his crops; who treats his land in the manner calculated to create and maintain these conditions, and above all, to perform these functions in the most economical and expeditious manner. He must clearly observe the requirements of a system of permanent agriculture, so that the productivity of his land—which is his working capital—does not deteriorate, and thus be able to hand on an inheritance to his successors which has not been dissipated during the period he has held it in trust.

This handbook attempts to present in outline the fundamentals of such a system. The use of complex scientific words and profound technical discussions have been scrupulously avoided, wherever possible; we recognise that the farmer is more interested in *what* happens than in *how or why* it happens. Moreover, it is not pretended that the discussions are complete or final. On the contrary, the book is intended to serve as an introduction

to the major subjects, and is an effort to create a more intelligent interest in the business of agriculture generally, and cane-growing in particular. It is thereby hoped that the farmer may be stimulated to seek a wider knowledge of the subject, which he knows must lead to a greater interest in his work, and a more profitable return therefrom.

Particularly is it desired that this handbook will be read and studied by the younger generation. The farm boy of to-day is the cane grower of to-morrow; and it is not sufficient that " what was good enough for my father is good enough for me. " Rather should the young farmer acknowledge that his father has reached a certain standard of efficiency with the knowledge and facilities at his disposal; that his is the obligation to regard this as the starting point from which to advance, and leave it in turn to his son to perpetuate the march of progress, without which the industry must fail.

One must pay tribute to the efforts of those who pioneered the industry in Queensland, often with means all too inadequate for the purpose; but the youth of to-day is faced with problems and responsibilities which are just as large as those of the early pioneering days, though the facilities at his command are immeasurably better for the job in hand. We can only hope that he will prove worthy of his trust.

H. W. KERR, Director.

Brisbane, 8th September, 1939.

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Chapter I.—SUGAR CANE.

HISTORICAL.

IT is believed that sugar-cane originated in Northern India, and it is mentioned in the ancient literature of that country. During the early centuries of the Christian era, the manufacture of sugar from cane is recorded. The first kind of sugar was simply concentrated cane juice, called "gur" in India, and is manufactured by the native races to this day. As early as the seventh century A.D. the art of making sugar from cane had spread, and it would appear that the Arabs and Egyptians learnt how to purify raw sugar by recrystallization, and to make a great variety of sweetmeats from the purified product. By the thirteenth century, a great many sugar factories existed in Southern China, and sugar could be bought freely at low prices.

By this time the manufacture of sugar in Southern Europe was widespread, and a well-defined sugar industry existed around the Mediterranean. But sugar manufacture received its greatest impetus with the discovery and development of the West Indian islands. Christopher Columbus introduced sugar-cane in Santo Domingo, on his second voyage, whence its spread to the neighbouring islands and countries of the mainland. By the end of the eighteenth century, the production of sugar in the American colonies and islands reached a total of 250,000 tons annually.

Then followed a period when world commerce expanded rapidly, and the production of sugar increased at a corresponding rate. The following summary of average annual world production over successive decades of the nineteenth century is particularly interesting:—

WORLD SUGAR PRODUCTION.

Period.	Average Annual Sugar Production.
	Tons.
1851–1860	1,750,000
1861–1870	2,750,000
1871–1880	3,500,000
1881–1890	5,000,000
1891–1900	7,500,000

These figures include both cane and beet sugar; the latter industry assumed prominence during the early years of the nineteenth century, and at the present time it is an important crop in practically all European countries.

The early years of the present century witnessed an increase in sugar production which far outstripped any previous expansion and reached its peak in 1930-31, when 30,000,000 tons of sugar were produced. Of this total, cane sugar constituted about 60 per cent. In 1928, Cuba alone produced over 5,000,000 tons of sugar, while Javan production attained almost 3,000,000 tons in the same year.

The earliest records of the cultivation of sugar-cane in Australia show that in 1823 the crop was grown successfully at Port Macquarie,

where 70 tons of sugar were manufactured. About 1850 cane was cultivated in certain Brisbane gardens, and in 1859 the first sugar was manufactured at that centre. Extensive areas were soon devoted to the crop, and in 1865 over 1,800 acres had been planted in the neighbourhood of Brisbane. It was soon discovered, however, that the severe winters experienced in these parts were most unfavourable to successful cane culture, and the industry rapidly expanded northward. The centre of the sugar industry has been gradually removed further and further from Brisbane, so that practically one-half of the entire crop is now grown north of Townsville. Sugar is at the present time Queensland's most valuable agricultural crop, and 8,000 canegrowers are engaged in its production. The cane is crushed by some thirty-three mills, most of which are provided with modern machinery for the efficient and economical manufacture of raw sugars.

The following table indicates the rapid expansion which the Queensland industry has undergone; this is most notable during the last fifteen years.

QUEENSLAND SUGAR PRODUCTION.

Year.	Sugar Production.
	Tons.
1892	57,000
1897	98,000
1901	120,000
1904	148,000
1907	188,000
1910	210,000
1913	243,000
1916	177,000
1919	162,000
1922	288,000
1925	485,000
1928	521,000
1931	581,000
1932	514,000
1933	639,000
1934	613,000
1935	610,000
1936	744,000
1937	763,000
1938	776,000

THE CANE PLANT.

Sugar-cane is a member of the family of perennial grasses; its cultivation is confined to the tropical and subtropical regions of the earth. Examination of a sugar-cane stem shows that in its general make-up it resembles other grasses very closely. These all possess jointed stems which are hard outside. and either pithy or hollow internally. The leaves are also similar in shape and arrangement on the stem. The root systems of the grasses resemble one another, while the flowers are simple in form and inconspicuous; there are no petals, and they do not exhibit showy colours.

The Stalk.—The stalk is roughly cylindrical, and is composed of a succession of sections or internodes separated by a characteristic "joint" or node. At the nodes are found "eyes" or buds, which are located alternately on opposite sides of the stalk. Immediately above each joint

appear one, two, or three rings of whitish spots; each of these spots marks an embryonic root. Under suitable conditions of temperature and moisture the eyes and embryonic roots will germinate to produce a shoot and root system respectively, and this characteristic provides the means of reproducing the cane vegetatively. In some varieties the eyes have a tendency to sprout while still attached to the parent plant; Oramboo provides an excellent example of this type.

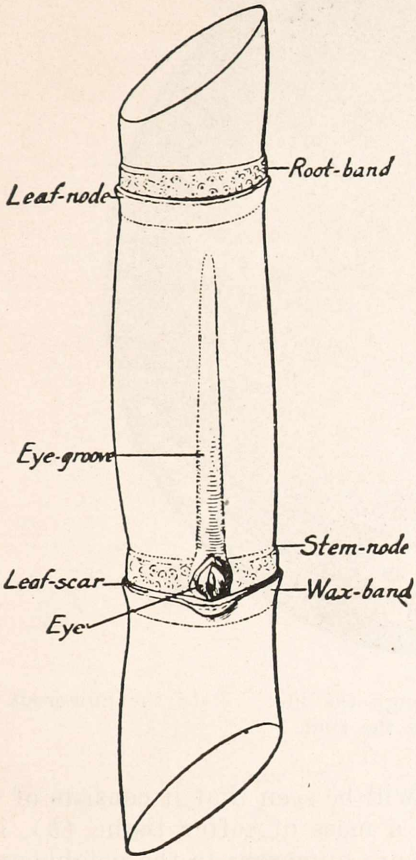

FIG. 1.—Illustrating the main features of the cane stalk.

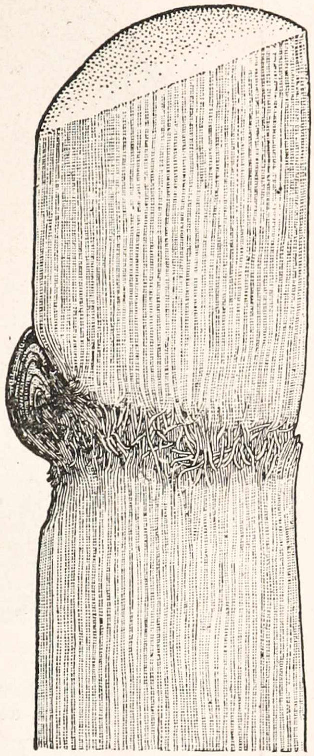

FIG. 2.—A vertical section through the cane stalk, showing the fibres, the bud or "eye," and the toughened node.

The colour of the stalk varies widely, and this characteristic is of assistance in recognising varieties. Some canes (such as B. 208 or P.O.J. 2878) are yellow or green, while others are greenish-brown, reddish-purple, and almost black as is the case with Badila. Some canes readily produce colour "sports," which have a striped or ribboned stem. It is generally found that, if a striped cane be propagated repeatedly, it will occasionally produce self-coloured stalks; that is, a striped sport showing green and red stripes may produce both pure red and pure green canes, each of which will grow true to colour, except for occasional striped sporting. It has not been proven that a colour sport is ever superior in yield or quality to the original variety.

The length between the joints varies considerably, depending both on the variety and the conditions of growth of the cane. Under adverse

conditions, Badila will produce joints 1 inch or loss apart, though the normal dimension is from 3-4 inches; certain of the P.O.J. varieties, on the other hand, have been known to carry internodes 12 inches in length, under exceptionally favourable conditions. The thickness of the stalk also varies from $1\frac{1}{2}$ to 3 inches.

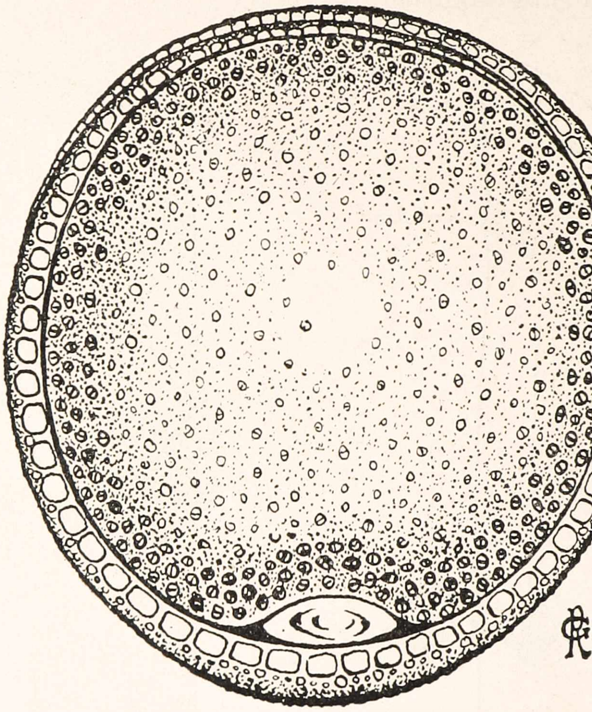

FIG. 3.—Cross section of cane stalk, through the bud. Note the numerous fibres at and near the rind.

If a cane stalk be cut across, it will be seen that it consists of three parts—(*a*) a hard, outer rind, and a mass of softer tissue (*b*), interspersed with fibres (*c*), these being more numerous in the neighbourhood of the rind. The rind serves as a protective coat for the softer internal portion of the stalk, and it is often covered with a coating of wax which assists in making it impervious to water. The softer tissue consists of large, thin-walled cells or sacs, in which is stored the sweet juice of the cane. The fibres consist of bundles of minute tubes, some of which carry water and plant-foods from the roots to the leaves, while others conduct the sugary juice manufactured by the leaves, to be stored in the pith cells of the stalk.

The stalk serves a threefold purpose in the economy of the plant:—(1) It supports the leaves and flower; (2) its system of fibre bundles serve to carry water and food from the roots to the leaves, and sugars from the leaves to the stem; and (3) the pith cells are the storage tissues for the sugars, which give the plant its economic value.

The Leaf.—The leaves occur alternately and oppositely, one at each joint. The leaf actually consists of two parts—the leaf sheath and the leaf blade. The sheath completely encloses the stalk for a distance of

from 6-12 inches, and is usually pale green in colour. The blade is attached to the sheath, and is from 2 to 4 feet long and 1 to 3 inches wide; in colour the leaves are various shades of green, depending on both variety and the fertility of the soil. When the cane is mature, the leaves die and shrink from the stalk; with certain varieties they fall away completely, leaving the bare stem.

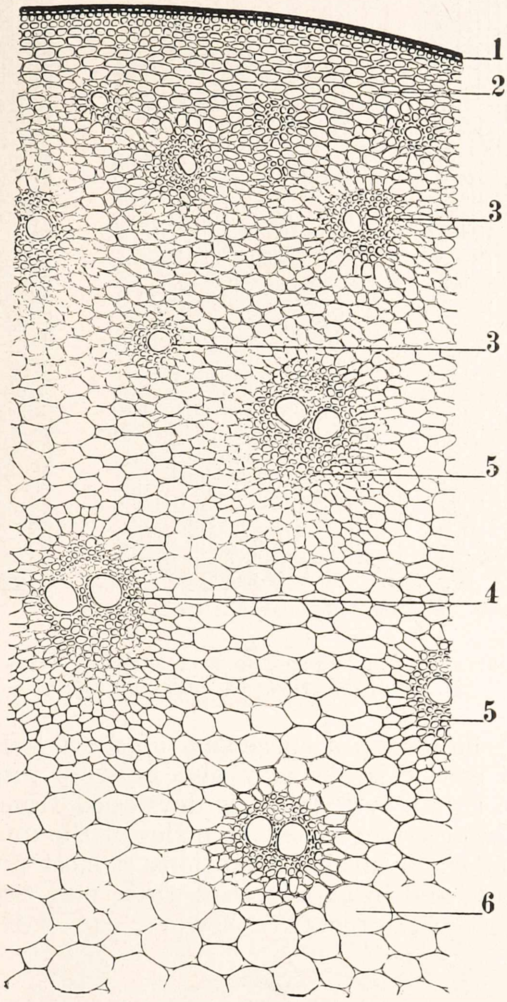

FIG. 4.—Enlarged section through the outer part of a cane stem; 1, outer rind; 2, thick-walled cells of the rind; 3, 4, 5, fibres of different sizes; 6, storage cells containing sugary juice.

The leaf is the "factory" of the plant, in which the green colouring matter is able, in the presence of sunlight, to utilize water from the soil and carbonic acid from the atmosphere in the manufacture of sugars. Both surfaces of the leaf are provided with minute pores through which they absorb the carbonic acid, and evaporate water vapour to the atmosphere. The process of plant growth will be discussed more fully in Chapter II.

The Root System.—When a cane cutting or "sett" is planted, the eye germinates to produce a new stalk, while the roots of the adjacent band also develop rapidly and provide a system through which the young shoot is able to procure its water and plant foods from the soil. As the

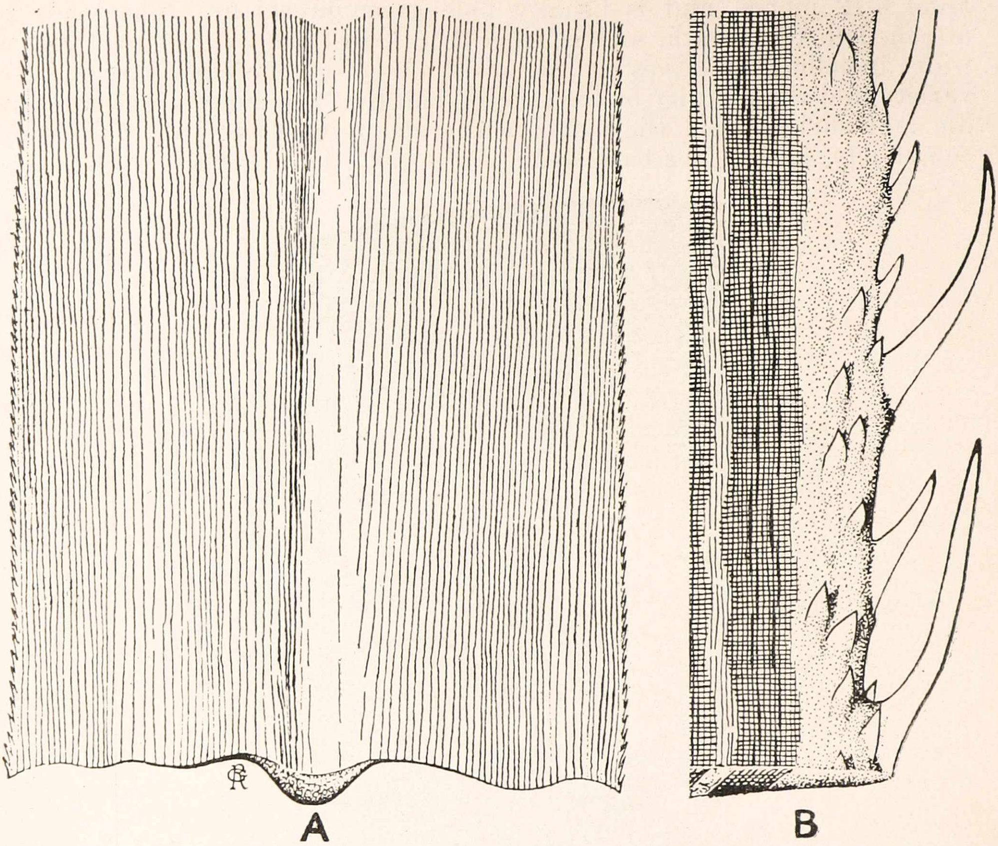

FIG. 5.—A, upper surface of a sugar-cane leaf showing veins and marginal teeth; B, enlarged view of marginal teeth.

shoot develops, it builds up a succession of short joints, each of which possesses a small eye; this eye may also grow to produce a secondary shoot, and thus a clump or "stool" is developed from the original bud. The roots of the stool spring from the nodes of the underground portion of the stems. Under favourable conditions, a most prolific development of roots takes place, and in an open soil, these may extend to a depth of 10 or 12 feet. Most of the roots are, however, concentrated in the uppermost foot of soil.

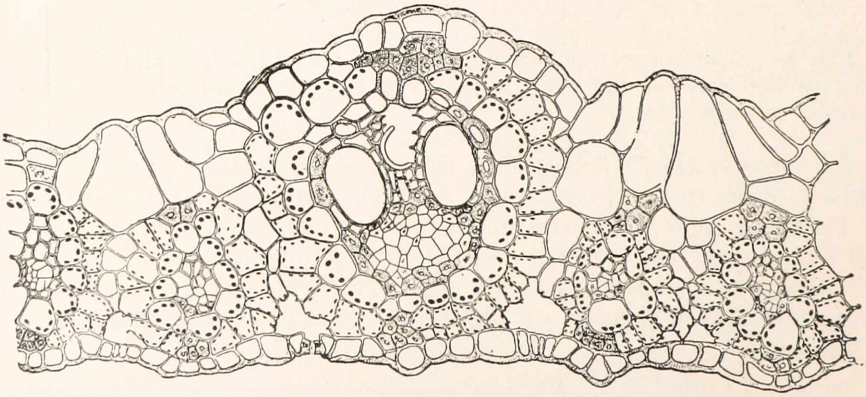

FIG. 6.—A cross section of the cane-leaf, highly magnified. One of the tiny "breathing pores" may be seen on the lower side, while the black dots in the cells are the small bodies which carry the green colouring matter. The centre of the picture is a vein, and the "tubes" are clearly seen.

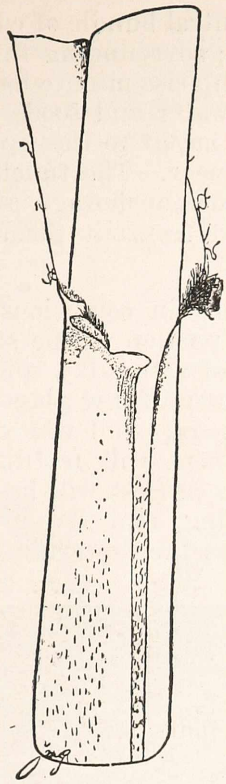

FIG. 7.—Showing the manner in which the leaf sheath is bound around the stalk, and the manner in which it is attached to the leaf blade (here not shown in full).

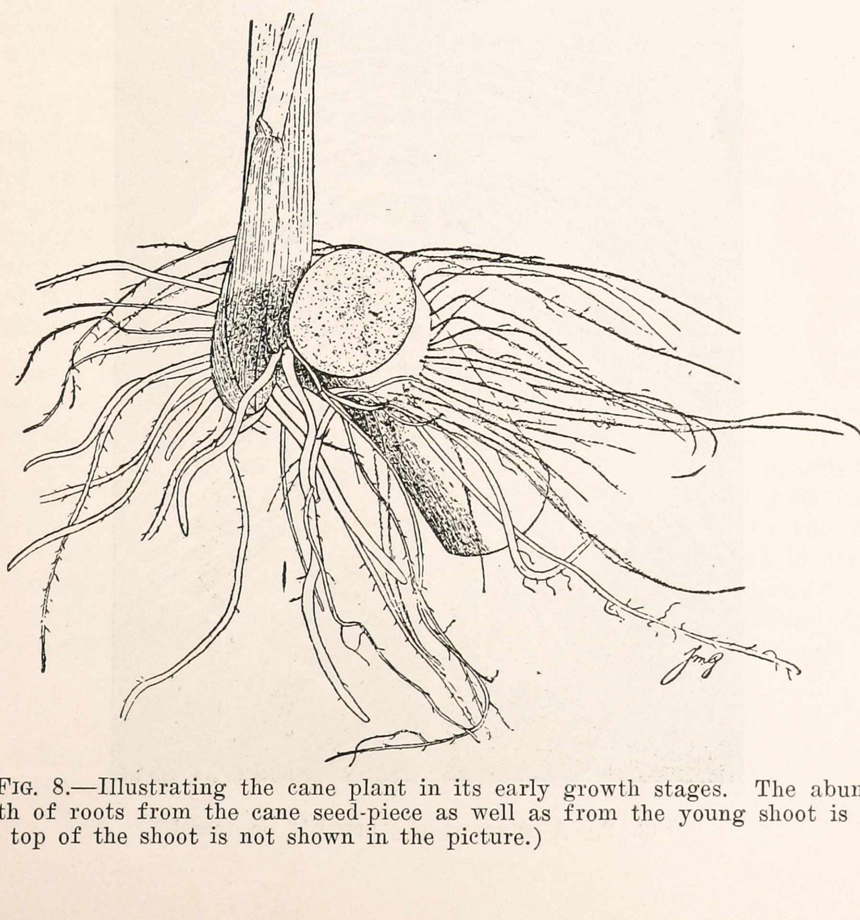

FIG. 8.—Illustrating the cane plant in its early growth stages. The abundant growth of roots from the cane seed-piece as well as from the young shoot is seen. (The top of the shoot is not shown in the picture.)

The root consists of a central bundle of conducting fibre tubes, rather similar to those of the stem; surrounding this is a layer of softer cells, from the outer layer of which arise minute hair-like roots which are most active in the absorption of water and foods from the soil. These hairs are clustered most freely adjacent to the tip of the root, and as the tip develops they die and disappear. The functions of the roots are firstly to provide the plant with a firm anchorage, and secondly to absorb water and food from the soil, and transmit them to the other parts of the growing plant.

The Flower.—Under certain conditions the cane stalk flowers or "arrows." The uppermost portion of the stem becomes elongated, and eventually produces a mop of soft, silky spikelets. Examination of the minute parts by means of a magnifying glass will show that each spikelet carries both pistil and stamens; and where conditions are favourable, pollen grains from the stamens will fertilize the female ovule of the flower to produce seed. This process will be discussed more fully under the heading of cane breeding, and the production of new varieties. Under Queensland conditions the flowering of the crop is by no means

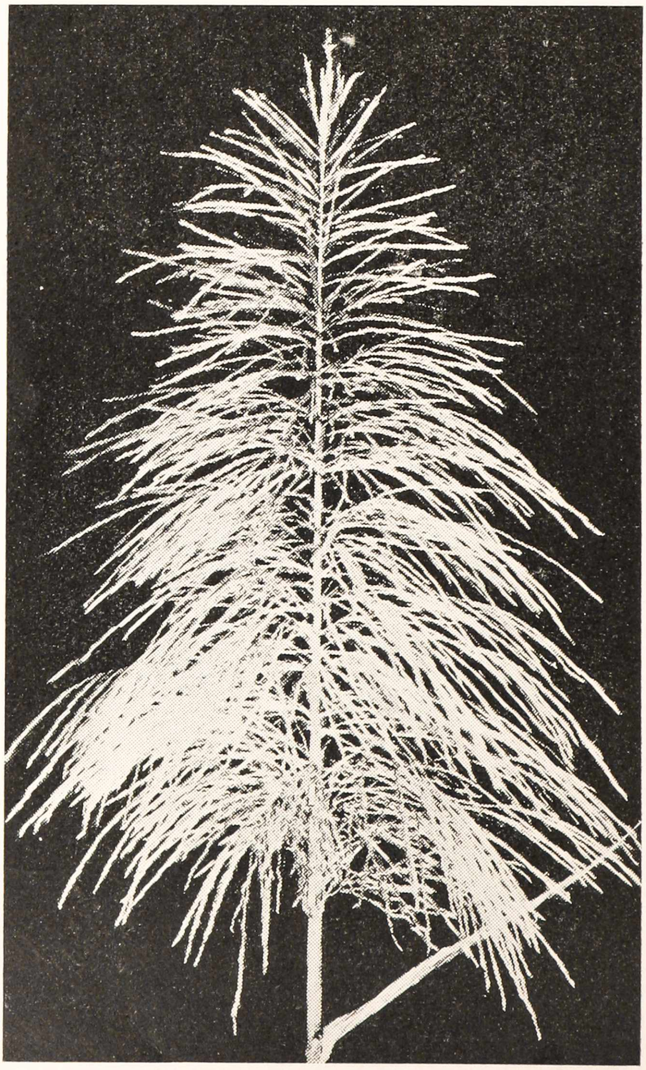

FIG. 9.—A sugar-cane "arrow" or tassel.

common. The extent of arrowing is governed by (*a*) the latitude, (*b*) the variety and (*c*) the season. In certain seasons, it is difficult to find a flowering crop in the southern districts. Since a stalk that has arrowed cannot produce any further cane stalk by elongation, varieties which flower early and freely are not favoured by the canegrower.

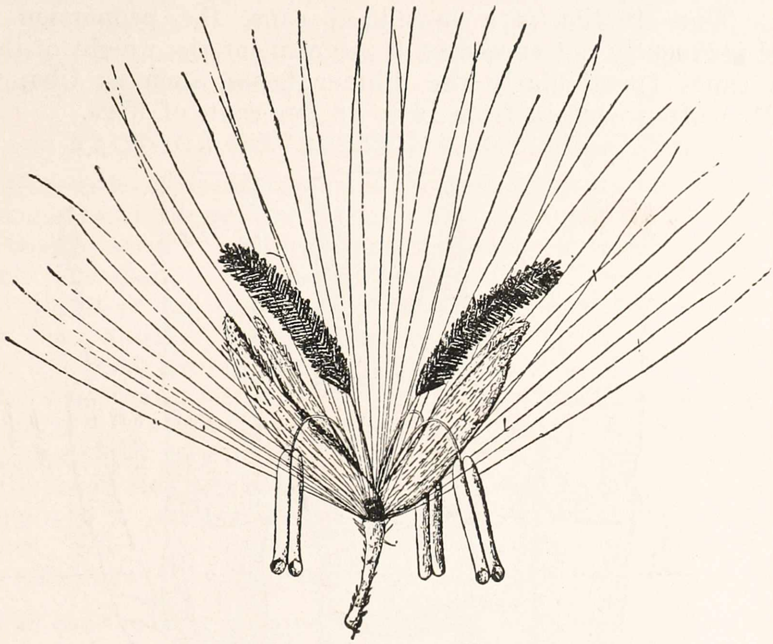

FIG. 10.—A cane flower highly magnified. The double tube-like organs are the stamens, which produce pollen; the dark, feathery-bodies are the pistils, on which the pollen grains fall and grow to produce seed.

The Root Stock.—If the cane stalks of a stool be cut off at the level of the ground, the stubble or root stock remaining in the ground will, under suitable conditions, produce a further series of young shoots. This process is known as ratooning, and the crop thus obtained is designated the *ratoon crop,* as distinct from the *plant crop* which is taken from the field following the replanting of the land. The ratoon shoots arise from the dormant buds of the root stock, which have not germinated during the stooling process of the preceding crop.

After harvesting the ratoon crop a further ratooning may follow; under most favourable conditions of soil and climate, ratooning may be continued over a long series of years. The ratoon crops are then designated first, second, third, &c., and as many as twenty ratoons have been recorded. In Queensland it is customary to harvest two ratoon crops before the field is ploughed out and replanted. On the older lands, only one profitable ratoon crop may be grown, while five or six cuttings are sometimes taken from one planting on the open-textured soils of the humid North. Usually the ratoon crops produce lighter yields than the plant cane, though this is by no means general.

COMPOSITION OF THE CANE STALK.

When the crop is mature, the green top and dry leaves or "trash" are removed, and the clean stalks form the product of commercial value. The composition of the stalk varies within rather wide limits,

and this is of considerable interest to the canegrower. When the cane is crushed by the heavy rollers of the mill, the pithy storage cells are broken up and the juice which they contain flows away. The portion of the stalk which remains when the juice is removed is known as *fibre*. The percentage of fibre in the cane is a characteristic of the particular cane variety, though it varies, also, due to variations in growing conditions. Thus Badila is a low-fibred cane, the proportion of this material frequently not exceeding 9 per cent. of the weight of the stalk. Certain canes (particularly the thinner types, such as Uba, Co. 210, P.O.J. 213) often contain from 16 to 18 per cent. of fibre.

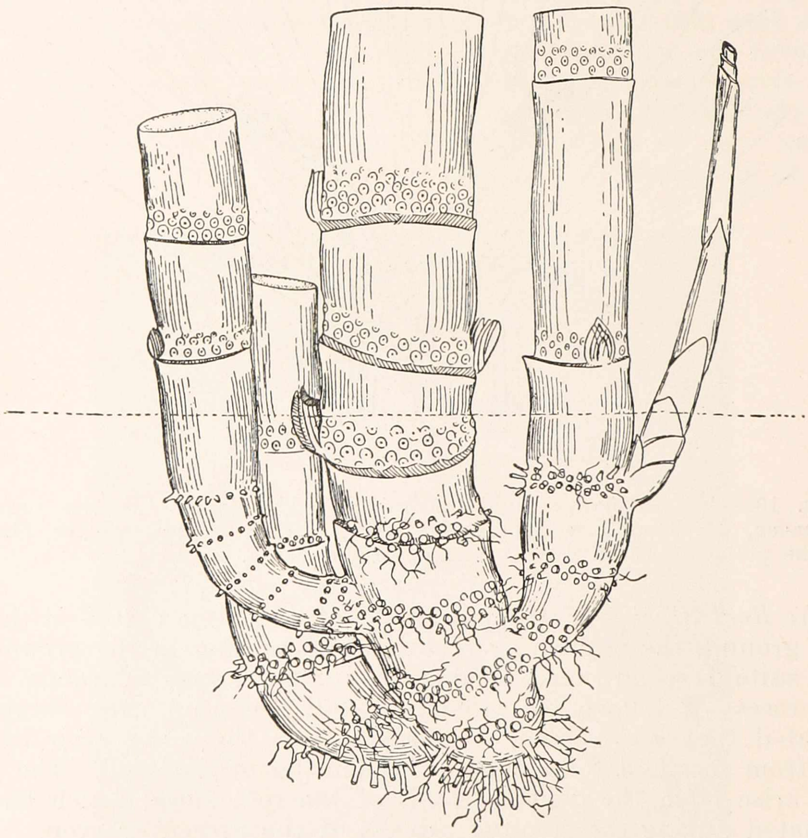

FIG. 11.—This picture shows very clearly the manner in which secondary shoots grow from the buds of the primary, and thus produce a stool of cane. (The upper portions of the shoots or stalks are not shown).

The cane juice itself varies widely in its composition. The percentage of sugars which it carries depends on (*a*) variety, (*b*) the state of maturity of the crop, (*c*) the climatic conditions of the locality. Thus Badila, S.J. 2 and Oramboo are spoken of as "sweet" canes, which means that at maturity the juice therefrom may contain as high as 20 per cent. of cane sugar; on the other hand, certain varieties never yield a juice containing in excess of 15 per cent. of sugar.

The process of sugar storage in the pith cells of the stalk is a gradual one. It commences when the cane first makes its appearance, and continues until the maximum is reached, usually between the months of July and November. Here again the variety itself is a dominating factor, for certain canes attain a high sugar content early in the harvesting season

(so-called early maturing varieties), while others are not "ripe" until late in the season. A third arbitrary class embraces those which mature in mid-season.

As the value of the crop is determined by the percentage of sugar which it contains, the harvesting of the cane at the height of maturity (*i.e.*, at its peak of sugar content) is a matter of the greatest importance to the farmer. This topic is dealt with more fully later. It is quite evident that a grower desires cane varieties which are low in fibre, which yield juices rich in sugar, and which mature successively during different months of the crushing season.

FACTORS GOVERNING CANE CULTURE.

In Queensland, sugar-cane is cultivated over a wide range of soil and climatic conditions. The "sugar belt" extends as an interrupted narrow coastal strip extending from Mossman (latitude 16 deg. S.) to Beenleigh (29 deg. S.) a distance of over a thousand miles. The annual rainfall of the cane areas varies from 40 inches to 180 inches. Cane is thus a highly adaptable crop, but it grows best in areas favoured by a high average temperature, and a humid atmosphere, while the plant requires large quantities of soil moisture during periods of prolific growth. It has been calculated that in the production of 1 ton of cane, about 150 tons of water are taken up by the roots of the crop, and evaporated from its leaves. In the production of a 30-ton crop, approximately 45 acre-inches of soil moisture are thus dissipated by the plants. Where the average rainfall is less than 60 inches a year, it may be concluded that irrigation will benefit the growth of the crop.

Sugar cane is most susceptible to frost, and even a light freeze will cause serious damage. It is for this reason that cane culture in Queensland seldom extends far from the coast. All varieties are not equally affected by frosts, while the damage due to freezing may vary in its nature. With certain canes the top may be killed but subsequent growth takes place from the "eyes" or buds of the stalk; with others, the buds themselves are also killed, and this facilitates the entry of rots which bring about a rapid deterioration of the stored juice. Areas in which damaging frosts are regularly experienced are, therefore, to be regarded as unsuitable for cane growing.

The ideal climate for cane is one in which the high summer temperatures coincide with the period of high (though not excessive) rainfall, accompanied by a spring and autumn season of moderate rainfall, and a relatively dry winter period with warm sunny days and cool nights. Under these conditions the crop makes prolific summer growth, which is followed by a gradual diminution in rate of crop production during which abundant sunshine ensures the rapid manufacture of sugars for storage in the pith cells of the stalk. In Queensland this ideal is seldom attained; in fact, these conditions are usually experienced only where irrigation practice is employed to regulate the soil moisture supply. Under such a system the alluvial lands of the dry Burdekin area are capable of producing very heavy tonnages of extraordinarily "sweet" cane. In the lower latitudes of the State, high cane yields are recorded in seasons of favourable rainfall, but it would appear that the relatively low winter temperatures—both day and night—do not provide the conditions necessary for the rapid manufacture of sugars for storage in the pith cells, and the resulting cane juice is therefore not so rich as that obtained from canes in the Central and Northern areas.

Although most varieties attain their maximum growth under humid tropical conditions, this is by no means uniformly true; while certain canes—such as Badila—make relatively poor growth when planted in the southern areas of the State, others which are standard canes for the lower latitudes are distinct failures when planted in the higher tropics. Canes vary also in their ability to withstand drought; in all probability this factor is closely related to the inherent rooting habit of the variety.

CANE YIELDS PER ACRE.

With the wide range of soil and climatic conditions under which the crop is cultivated in Queensland, it is only to be expected that yields per acre will vary accordingly. On virgin soils of high fertility, and with favourable rainfall, as much as 70 or 80 tons of cane per acre have been produced for an annual crop. On older lands, and under droughty conditions, yields may fall to 5 tons per acre or less. As an index of the magnitude of the crops which are harvested from the major divisions of the State the following averages for the ten-year period 1928-1937 are of value. The highest and lowest annual yields for the period are also included to show the range of variation from year to year:—

——	Average Annual Yield 1928-37.	Highest Yearly Average.	Lowest Yearly Average.
	Tons.	Tons.	Tons.
Mossman to Ingham	21·1	24·9	18·1
Lower Burdekin	25·8	33·8	21·2
Proserpine	13·1	17·0	8·4
Mackay to St. Lawrence	13·8	17·4	11·5
Bundaberg	15·7	22·1	7·4
Maryborough, Childers	13·6	19·5	6·7
Nambour, Beenleigh	16·1	19·7	12·8
Average—All Queensland Districts.. ..	18·5	21·1	15·9

The average yield of sugar per acre varies in a similar manner. There is, however, a reasonable degree of constancy in the average sugar content of the cane for *all* areas, despite a marked variation from district to district. This may be expressed in terms of the tons of cane required to make a ton of sugar; for the past fourteen years the averages were as follows:—

Season.	Tons of Cane per ton of Sugar.	Season.	Tons of Cane per ton of Sugar.
1924	7·75	1931	6·94
1925	7·55	1932	6·90
1926	7·52	1933	7·31
1927	7·32	1934	6·97
1928	7·18	1935	6·92
1929	6·91	1936	6·94
1930	6·83	1937	6·73

It will be observed that there has been a progressive reduction in this value over the period; this is due in part to each of the following factors:—(*a*) the planting of varieties richer in sugar; (*b*) a reduction in the crushing period allowing the cane to be harvested when at its peak of ripeness; (*c*) improved milling work making for increased sugar recoveries.

Queensland enjoys the distinction of producing canes richer in sugar than those of any other cane country.

Chapter II.—THE SOIL.

INTRODUCTION.

In order that the farmer may fully appreciate the discussions which follow, it will be necessary to describe briefly the make-up of soil and its function in crop production.

Soil may be defined as the upper, friable layer of the earth's crust. It consists for the most part of mineral matter, resulting from the breaking up and decay of rocks. The transition from solid rock to mature soil may usually be traced in road or railway cuttings. This slow process of rock decay is proceeding continually, and is brought about by the destructive forces of nature, the chief of which are—

(1) Heat and cold which cause splitting and cracking of the rocks.

(2) Water which enters these fissures and exerts a chemical and dissolving action; and where frost is experienced, the sudden expansion which accompanies freezing acts as a wedge to drive the rock masses apart, and split them into smaller grains. In times of heavy rain it carries away the fine particles and exposes fresh surfaces.

(3) The gases of the atmosphere assist the water in its decomposing action and help very materially in the leaching of the substances thus produced.

(4) Wind acts as an abrading agent when it drives dust and sand particles against the solid rock.

(5) Surface growths of lichens and mosses which are frequently seen on decaying rocks produce acid substances which serve as active solvents for the rock minerals.

The process of soil formation is thus a complicated one; moreover, the forces which are active in the production of the soil also function in the soil itself, and indeed, their activity in this respect is largely responsible for the supply of many important substances which nourish the plant.

CLASSIFICATION OF SOILS.

It is reasonable to expect that the nature of the soil will be governed by the nature of the parent rock from which it is formed, and the conditions under which the process has taken place. That this is so is evident to all canegrowers. Even on an individual farm one may frequently observe three or four distinctive soil types, differing in colour, depth, general physical conditions, and productivity.

If it were possible by means of a series of sieves of varying mesh-size to separate the soil into the grains of different dimensions, it would be found that soils vary considerably in their make-up. Some contain a preponderance of sand grains with little of the finer materials; such soils are classed as *sands* or *sandy loams.* Others contain but little or no sand, but are composed chiefly of so-called "silt" and the still finer clay particles. These are the *silt loams, clay loams,* and *clays.* Intermediate to these extremes there exists that class which contains sensibly equal proportions of finer and coarser grains, and in its general behaviour exhibits neither the gritty characteristics of the

sands nor the sticky quality of the clays. These are known as *loams*. The classification of soils on the proportions of their constituent particles is a natural, commonsense one, which is most valuable. The nature of the individual grains has a most important bearing on the behaviour of the soil under cultivation and its relationship to moisture retention.

Clays, for example, are notable for their capacity to absorb and retain large volumes of water, and possess decided drought-resisting properties. Further, it is found that the degree of fertility of the soil is generally closely associated with its content of clay particles; clays are therefore usually well endowed for the production of heavy crops, but they possess the drawback that difficulties attend their successful cultivation. Under tropical rainfall conditions it is frequently impossible to deal effectively with these lands, and they are not favoured for cane culture. Sands, on the contrary, are excellent from the point of view of tillage, but they are deficient in their capacity for moisture retention, and are notoriously droughty, while the absence of a reasonable proportion of clay particles usually denotes poverty. They also are generally unsuited to cane production.

The loams must be regarded as the most valuable cane soils. They are best adapted for cultivation under conditions of heavy rainfall, and if not naturally endowed with a high degree of productivity, it usually pays to supplement this deficiency by the use of fertilizers. Silt loams and clay loams are also satisfactory, and they constitute a large proportion of the canelands of this State.

Sandy soils, because of their adaptability to tillage, are known as "light" soils; clays, on the contrary, are termed "heavy" soils because they are much more difficult to till. By *weight*, however, sand is the heavier soil and clay is much lighter.

Another method of classifying soils is based on the manner in which they were formed or built up. Two main groups of this classification are of special interest to Queensland canegrowers, and these will be discussed briefly. All soils (other than peats) are the products of decomposition of the rocks which constitute the earth's crust. As this process continues the soil particles thus formed may accumulate in the position where they are formed, and they obviously are closely related to the rock mass by which they are underlaid. Such are known as *residual* soils. Sometimes they are of extreme depth, as is the case with red volcanic loam, which is formed by the decomposition of basaltic rock. Schists and shales, on the contrary, usually yield shallow soils.

Due to the action of running water which flows from the land surface in times of heavy rain, the finer particles of soil may be carried away and eventually find their way to the creeks and rivers which may carry them to the ocean. The ability of running water to transport soil particles depends very largely on the speed of flow of the stream. In times of flood, the surging torrent may carry a heavy load of "mud" and sand; should the stream break its banks, the sudden check in flow causes the flood waters to deposit their load in the form of a "silty" sediment. In this way, soil masses are gradually built up, which are evidently foreign to the rocky substratum on which they rest. Such are known as *alluvial* soils. They are usually deeper soils than those of residual origin, and their depth is a decided asset to the canegrower. Moreover, as the sediments which compose the alluvials

are frequently brought hundreds of miles from regions of relatively low rainfall, they are generally of high fertility. Such are the alluvial loams of the Burdekin district.

In texture, the alluvials vary from the fine sands and silts which occur adjacent to the banks of the stream to the clay loams and clays which are usually laid down on the more remote margins of the flood plain.

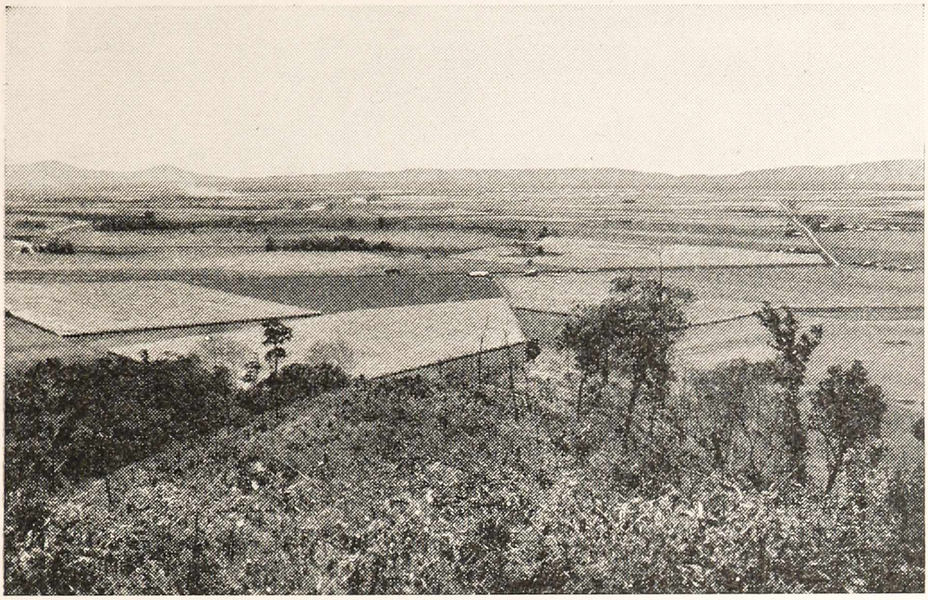

FIG. 12.—General view of the alluvial lands of the Johnstone Valley, Innisfail District.

An interesting study in these two classes of soil is afforded by the lands of the Tully area. The gravelly loams of granitic origin are essentially the residual "skeleton" of the decomposed rock mass, and are composed in the main of coarse sand or gravel particles; under the heavy rainfall conditions which characterise the district, the finer silt and clay grains have been carried away, and constitute the sediments from which the river lands were built up.

A third system of soil classification is freely employed in Queensland. This is based on the type of natural vegetation which clothed the land surface in its virgin state. In the cane areas two main classes are recognised—(*a*) *scrub soils*, (*b*) *forest soils*. The scrub soils carried, as a rule, a dense jungle growth of soft-woods and vines, while they are characteristically open in structure and of good depth. They usually exhibit no pronounced transition from soil to subsoil. Though frequently of high fertility, this is not invariably true. The natural vegetation of the forest soils consists usually of hardwoods, though the trees may vary widely in size and density of population, depending on factors such as rainfall, soil texture and fertility. They generally exhibit a well defined subsoil, and are rather generally less fertile and deep than scrub soils formed under similar climatic conditions. An intimate study of the natural vegetation often affords a definite indication of the characteristics of the land, and experienced farmers commonly employ this knowledge in their selection or evaluation of agricultural lands.

FIG. 13.—The rich red volcanic lands of the Woongarra area, viewed from The Hummock, Bundaberg.

The following table provides a brief classification of the major cane soils of Queensland. These particulars are necessarily generalised in their scope, and growers desirous of more detailed advice regarding their soils should seek the assistance of the Bureau field officer who visits the area, or of the Experiment Station chemist if one be located in the district.

SOIL CLASSIFICATION TABLE.

District.	Major Soil Types.
Mossman to Ingham	*Alluvial* silts, loams, and clay loams, of granitic, schist, or "mixed" origin. *Residual* loams, sandy and gravelly loams, of granitic, schist, or volcanic origin.
Lower Burdekin	*Alluvial* sandy loams, loams, and clay loams, of granitic origin. Sediments transported from dry western areas.
Proserpine to St. Lawrence ..	*Alluvial* silts, loams and clay loams, of granitic origin. *Residual* loams and sandy loams from sandstones and shales.
Bundaberg	*Alluvial* loams and clay loams of granitic origin. *Residual* loams and sandy loams from sandstones and shales, and of volcanic origin.
Childers	*Residual* red volcanic loams with small areas of alluvials and residual loams from sandstone and shale.
Maryborough	*Alluvial* loams and clay loams of mixed origin. *Residual* loams and sandy loams from sandstones and shales, or of volcanic origin.
Moreton and Southern Districts	*Alluvial* loams and clay loams of mixed origin. *Residual* loams and sandy loams from sandstones and shales.

THE COMPOSITION OF THE SOIL.

It is obvious to any farmer that his soil is composed essentially of mineral grains with a greater or less amount of organic material. Now these individual mineral grains are not uniform in their composition, and this fact is of the greatest importance from the point of view of the nourishment of the crop. Careful study of the factors which influence plant growth shows that the function of the soil is to supply the plant with food and water. The water is absorbed by the roots, and the food can enter only when dissolved in the soil moisture. Further, it is found that the soil foods which the plant *must* have for its growth are well-defined chemical substances, and are seven in number; their names are—nitrogen, phosphorus, potassium, sulphur, calcium (lime), iron, and magnesium. These are the *essential* plantfoods, though the plant may absorb in addition other accessory mineral substances. What is the source of these materials, and how are they held by the soil to yield them to the plant as required?

The answer to the first question is found in the slow process of rock and mineral decay which is instrumental in the formation of the soil itself. The several minerals which constitute the rocks from which fertile agricultural lands are derived possess their own characteristic composition, and they also vary widely in the speed with which they are broken down or rotted, and yield their simpler plantfood substances. Quartz particles, for instance, are highly stable and remain in an unchanged condition; they usually make up the bulk of the sand grains of the soil. Quartz is a mineral which yields no essential plantfood Other minerals (so-called felspars) decompose rather readily, and supply lime and potash; the micas which are so frequently observed in the cane lands of North Queensland decompose less speedily, but they eventually yield potash, iron, and lime; other specialised minerals provide lime and phosphorus (phosphate), while the darker coloured minerals of the rock supply magnesium and iron. The characteristic strong red colour of certain soils is due to the presence of large amounts of iron compound formed from the rotting of iron-bearing minerals in which their parent rocks abound.

Rocks themselves vary in the kinds and proportions of the minerals in their make-up, and it is therefore evident that the soils formed therefrom will vary in their ability to provide the desired plantfoods for the nourishment of crops, and this factor exercises a dominating influence in the matter of soil fertility. In point of fact, there are other important factors such as rainfall, temperature, vegetation, &c., which modify this property of the soil in that they govern the ability of the land to *hold* the plantfoods when they have been given up by the minerals, but this will not be discussed in detail. Suffice it to say that, other things being equal, under relatively dry conditions available plantfoods are stored in the soil, while excessive rains tend to the rapid removal of the plantfoods as they are liberated—the oft-discussed process of *leaching*.

In the above discussion no reference was made to the source of nitrogen and sulphur. Most rock minerals contain small proportions of sulphur compounds which eventually become available to the plant, but a large proportion of this food and *all* of the nitrogen of the soil is

associated not with the mineral but with the *organic* matter of the soil. This is the important soil constituent which arises from the decomposition of plant and animal remains, and will be discussed in some detail under the section devoted to **Humus**.

HOW PLANTS GROW.

The reader may now be able to follow the process by which plants feed and grow. The explanation of this phenomenon remained a complete mystery until quite recent times. One theory which was advanced as recently as three centuries ago stated that a plant was nothing more than water that had undergone a mysterious change in the soil! It is only within the last century that the close resemblance between the composition of the soil and of the ash of plants was demonstrated, and the subsequent studies which this discovery stimulated has provided us with a fairly complete picture of the process of plant growth.

The major raw materials from which plant tissues are manufactured are water and carbon dioxide. The water supply enters the plant through its roots; carbon dioxide (or carbonic acid) is a gas which is formed when plant or animal products decompose, and is present in the atmosphere to the extent of about one part in 3,000 of air. This gas enters the leaves of the plant through numerous minute pores with which the surface of the leaf is provided. These two materials are built up into sugars through the agency of the green colouring matter of the leaf (called *chlorophyll*). Like all factories, a source of energy is required to enable the finished products to be manufactured, and this the plant leaf derives from the light of the sun. The simple sugars thus produced provide in turn the starting point for the manufacture of more elaborate plant materials such as starch, cellulose, fibre, proteins, waxes, and so on, while in the cane plant the farmer is particularly interested in the fact that large amounts of surplus cane sugar itself are stored in the pith cells of the stalk.

It is found that water and carbon dioxide actually contribute over 98 per cent. of the weight of the cane plant; the remaining small proportion, though relatively insignificant in amount, is absolutely essential to the success of the process. This is the material which the plant obtains from the soil dissolved in the soil moisture, and which is ultimately derived from the decay of rock minerals and soil humus.

We may now summarise the principles of soil fertility and plant nutrition. The process of soil mineral decomposition provides the soluble by-products which are the soil foods for all crops, and which enter the plant roots dissolved in the soil moisture. This moisture is the "life-blood" of the crop and is continuously entering the roots, to be evaporated finally through the leaf pores, in the form of vapour. The plantfoods withdrawn from the soil remain in the leaves as raw materials for our factory, the plant, and without which the factory would be idle. Though small in actual amount, these mineral foods are absolutely essential for plant growth. The fertility of the soil is measured by the amount of the plantfood reserves retained by the soil in such a form as to be absorbed readily by the crop roots. In regions

of moderate or low rainfall the accumulation of these so-called "available" plantfoods may assume high proportions, and we recognise such soils as rich or fertile. On the other hand, the soils of the heavy rainfall areas are exposed to the leaching action of excessive soil moisture, which tends to remove the soluble plantfoods as rapidly as they are produced.

As cane growing is an industry of the high rainfall districts, we would be forced to conclude that the soils devoted to it are not characterised by a high degree of fertility, and this is indeed true. We shall discuss this question in detail under the heading of **Fertilizers** and we will learn that the canegrower must pay special attention to the question of soil fertility and the supply of adequate plantfoods for his crop.

Chapter III.—THE SOIL WATER.

It has already been stated that water is an essential "food" for the plant, as it takes a very definite part in the fundamental process of sugar manufacture in the leaf of the plant. Moreover, the cane stalk itself contains over 70 per cent. of water, in the form of the sugary solution of the storage cells. But the quantity of water utilized in these processes is but a very small proportion of the total amount absorbed from the soil by the crop roots. As soil moisture deficiency is so frequently a factor limiting cane growth in Queensland, it is important that the farmer have a clear understanding of the manner in which it is held by the soil, and the various functions it performs in the plant.

Water serves the following purposes:—

(1) It is a *nutrient* or food.

(2) It carries to the manufacturing parts of the plant the soil food and carbonic acid, and takes away the manufactured products for use or storage by other parts of the plant.

(3) It keeps the cells turgid or expanded and prevents wilting. When plants cannot get all the water they require they wilt, and when they remain wilted they die.

(4) The evaporation of water from the leaves acts as a cooling agent, and prevents them from becoming too warm.

(5) It serves as a medium in which the chemical or life processes of the plant are performed.

(6) In the soil it is also necessary to enable the solution of plant-foods and to permit the soil organisms to do their work.

In the growing plant, there is a continual stream of water rushing through the tubes of the roots and stem and the veins of the leaf, to make up for the evaporation which takes place through the pores of the leaf surface. The amount of water which is thus utilized by the cane plant has been estimated, and it is found that, in the production of 1 lb. of dry matter, about 30 gallons of water are used by the cane plant. By simple calculation it follows that the production of 1 ton of cane involves the utilization of about 1½ acre-inches of soil moisture.

The economy of water utilization varies considerably, and is dependent on the weather, the water supply in the soil, and the fertility of the land. Plants use more water in hot, dry weather than they do in cool or humid weather. Moreover, the greater the supply of water in the soil the more lavishly is it used; and a fertile soil, (or one that has been adequately manured), will make more economical use of water than one which is low in fertility. However, the average figure of 1½ acre-inches per ton of cane may be taken as a reliable basis for our argument.

It is therefore evident that a 30-ton crop of cane will absorb about 45 acre-inches of water from the soil in the course of its lifetime. To provide this quantity of available soil moisture would demand a considerably greater amount of rainfall, when it is remembered that a large proportion of this may be lost in surface run-off, or by percolation through the soil to lower levels than the absorbing roots penetrate. In addition, a further proportion of the soil moisture is lost by evaporation from the moist land surface.

It should be clear to the canegrower that in regions of irregular and uncertain rainfall, there must occur periods when moisture deficiency prevents normal growth, and the above facts present a ready explanation why cane, unaided, does not yield heavily in the regions of low rainfall. Although the farmer is powerless to improve rainfall conditions, he can do something to provide for the better utilization of what is received by the land.

We must first understand just how the soil holds the moisture which it contains. It has been stated that the soil is an aggregation of loose particles or grains of various sizes—from relatively coarse sand to the finest clay and containing a variable amount of waxy humus. These individual grains are usually bound loosely together into the form of crumbs or granules, the "cementing" material being the clay or humus. Between the soil crumbs, and within the crumbs themselves are minute spaces which, in a dry soil, are filled with air. When the soil is moistened, the water drives out the air from the fine pores and the soil becomes, temporarily, a mixture of solid particles and water, in about equal proportions by volume. Should the soil be left undisturbed, it would be found that much of this water will seep down into the lower soil layers, leaving the surface moist, but not visibly wet. In the course of two or three days the percentage of moisture in the soil is reduced to an amount at which it remains sensibly constant, provided loss by evaporation is prevented. The quantity of moisture which the soil will hold in this way is a characteristic of the particular soil, but varies considerably from soil to soil.

Careful study of moist soils has shown that the water is held on the surface of the individual soil grains in the form of thin films, which are so firmly held that the force of gravity is unable to pull them away. As might be expected, the quantity of moisture held by the soil is governed by the amount of surface exposed by the grains in a given weight of soil. Sandy soils have a relatively small total surface area, and hold little water; clays, on the other hand, expose a large internal surface, and possess a high water-holding capacity. Further, it is found that the soil humus has a very much greater capacity for holding moisture than either sand, silt, or clay. The relative water-holding capacity of these three substances is as follows:—

Sand ..	..	10-15 per cent. of dry weight
Clay ..	..	40-50 per cent. of dry weight
Humus	..	200 per cent. of dry weight

It is therefore clear why a sandy soil is a droughty one, and a clay is able to support plant growth for a prolonged period following rain. The figures quoted also show the tremendous value of soil humus in its contribution to the moisture-retentive capacity of the land.

Although the soil grains are able to hold these films of moisture against the pull of gravity, the roots of a growing crop are able to absorb the water freely, and they continue to do so until a point is reached beyond which growth is no longer possible unless rain falls. When this point is reached it is found that the soil is not devoid of moisture, but that which remains is so firmly held by the soil grains that the roots cannot withdraw it. This is the point at which the crop becomes permanently wilted. Measurements have shown that the moisture content of the soil at which this happens varies with the soil type. With sandy soils the percentage of moisture at the wilting point is much lower than is the case with a clayey soil.

We may therefore regard the amount of moisture *available* for crop growth as the difference between what is held by a well-drained soil and the moisture percentage at the wilting point. The following table provides some idea of (*a*) the amount of water different soils will hold, and (*b*) the amount which is available for plant growth. In each case, the amounts have been calculated as inches of water per acre of soil, 1 foot deep.

Soil Type.	Water-holding Capacity.	Water Available for Plant Growth.
	Acre-inches.	Acre-inches.
Sandy loam	$2\frac{1}{2}$	2
Loam	$3\frac{1}{2}$	$2\frac{3}{4}$
Clay loam	5	$3\frac{3}{4}$
Peat	10	7

It should also be stated that sandy soils give up their water much more readily and completely than loams or clays, and crops grown thereon are more lavish with it. It is for this reason that plants are better able to withstand a dry period when growing on a clay loam than when growing on a sandy loam.

Although it has been pointed out that the bulk of the fertility of a soil is contained in the surface soil, it should also be emphasised that the subsoil layers are capable of storing large quantities of moisture which may be drawn upon by the deeper crop roots, provided care has been taken to maintain the subsoil in an "open" condition by suitable tillage methods. It is common experience, for example, that a loam possessing a clayey subsoil of an open nature is much more drought resistant than a similar surface soil underlaid by sand.

The farmer must therefore regard his soil and subsoil as the storehouse for the water which falls on the land during rainy spells, and on which his crops must subsist during the dry period which follows. Moreover, it should be his aim to create those soil conditions which favour the free and complete absorption of the rainfall, and thus eliminate losses by surface run-off; the water which leaves the land surface in this way is quite incapable of adding anything to his yields. By careful attention to the important question of conserving and ploughing into the land all available forms of organic matter, he is able to build up the humus content of the soil. The presence of this soil ingredient confers upon the soil an increased moisture-holding capacity, while contributing substantially to the ease with which the soil may be maintained in a condition of good tilth.

Chapter IV.—SOIL ORGANISMS AND HUMUS.

Following the discussion on soil forming processes and the nutrition of plants by plantfoods which are thus released, it might be concluded that the soil is a lifeless, inert mass. This is, however, far from true. Though our cane soils are essentially mineral in character, they do contain a small proportion of material which is not of *mineral* but *organic* origin. That is to say, it consists of the remains of plants and animals which have slowly accumulated in the soil, and it is actually one of the most important factors in determining soil fertility. The soil organic matter or *humus* as it is most frequently called provides the entire source of the essential plantfood *nitrogen,* without which the soil would be sterile. The question of humus and its functions in the soil will therefore be discussed in some detail.

SOIL ORGANISMS.

If a grain of fertile soil were magnified one billion times or more, it would be seen as a mass literally teeming with life. The greatest number of organisms (*bacteria*) would be observed as short rods or spheres just clearly visible at this magnification. What is the purpose of these minute individuals? What is the nature of their food? In what way do they benefit the soil and crop?

When one speaks of bacteria, the lay mind immediately conjures up visions of dread diseases of man and plants. Actually, the proportion of bacteria which are responsible for these visitations are insignificantly few, and by far the greater number are helpful types which perform a duty without which life as it is known on the earth to-day would not be possible. It is commonly observed that the remains of plants and animals do not accumulate, but are slowly dissipated by the process of decay. This process is none other than that by which the minute organisms of the soil—which is their natural home—secure food for their energy and reproduction.

The method by which they absorb their food is in itself most interesting. These simple forms of life have no complex digestive system such as characterises the higher animals. On the contrary, they are forced to secrete digestive juices which act on the complex plant and animal remains, and reduce them to simpler forms, in which condition they are soluble in water and may then be absorbed through the cell walls of the organism. The power to deal with these organic substances is not the same for all classes of bacteria, and a high degree of specialisation exists amongst those groups which are equipped to deal with the more resistant types of food. Thus most all bacteria are able to absorb sugars and starches which are relatively simple in their make-up. Little difficulty is experienced also with the simple proteins or nitrogen compounds; but the woody parts of plants and horny parts of animals are much more resistant to decay, and only a few types of organism are able to bring about their decomposition.

Whatever the nature of the process or the speed with which it is carried out, the net effect is the reduction of the respective complex forms of matter to their simplest state. This is a consideration of the greatest importance to the agriculturist. It has already been stated that the plant absorbs foods from the soil and air, and in its green leafy parts it uses these simple substances in building up the many and varied

tissues of its structure. The process of bacterial decay is, then, one in which the plantfoods are again liberated for use by successive crops. The importance of maintaining a liberal supply of decomposing organic matter in the soil is thus evident; a rich garden soil is one in which large amounts of animal manure or crop refuse have been incorporated, and the greater the amount of organic material which has been added in this way, the more readily is the soil able to supply the plantfood needs of the crop which it supports. In addition to these foods, the process of decay liberates acid substances which are able to attack the mineral particles of the soil and thus speed up the rate at which they decay and add to the available food supply of the land.

The plantfood nitrogen which is entirely associated with the soil organic matter is also the most expensive substance added in artificial manures, and is the plantfood which is probably most effective in regulating cane production. A soil rich in humus is therefore a highly desirable cane soil, and many of the virgin scrub lands of the Queensland cane areas actually fulfilled this requirement. But, unfortunately, the humus supply of the land became rapidly depleted by continuous cultivation under conditions of relatively high rainfall and high average temperatures. In its natural state the soil remained in an undisturbed condition, was kept relatively cool by the heavy cover of vegetation, and was continually receiving the falling leaves and other remains of the plant species which it supported. The plantfoods which were released on the land surface by organic decay were rapidly absorbed by the plant roots which permeated the soil; these were built up into the several plant tissues to be returned once more to the soil when the plants perished or its leaves fell. The process was then one of fertility building.

The removal of the natural vegetation rudely interrupted this natural process. The accumulated fertility of the soil was immediately placed at the disposal of the economic crop which was planted, and aided by cultivation of the land, the soil organisms found conditions ideal for an accelerated rate of humus decomposition. Doubtless, the crop flourished under this combination of ideal conditions; but instead of returning the plantfood and humus-producing crop substances thus manufactured, the farmer must sell the crop, and with it departs a large measure of soil fertility. If such a process were repeated year after year with no attempt at restoring the supply of plantfood or soil organic matter, it is obvious that the land would rapidly be reduced to a condition of low productivity.

It should be so obvious from this discussion that the practice of continued intensive cultivation of cane land must inevitably lead to bankruptcy of the soil, that it is astounding how the farmer in this country still requires to be convinced of the wisdom of guarding all sources of plant organic matter for restoration to the land.

RESTORATION OF SOIL HUMUS.

Fortunately there are ready means available to the canegrower whereby it is possible to stem the tide of humus depletion of his soil, and even to add appreciably to the supply. The customary methods may be discussed under the headings—(*a*) green manuring, (*b*) trash conservation, and (*c*) fallowing. Methods (*a*) and (*b*) may be practised during the progress of cane cultivation, but method (*c*) demands the elimination of the land from cultivation for a period of years.

Green Manuring.

Green manuring is the name given to the practice of growing a crop of some suitable plant species, which, at the height of its growth, is ploughed under to decompose and enrich the soil. This policy has become firmly established amongst Queensland canegrowers, though doubtless there are still many farmers who fail to appreciate the value of this excellent practice. At the present time every canegrower is obliged to fallow one quarter of his land each year, and green manuring affords a simple, convenient, and inexpensive method by which the fertility of the land might be improved during the fallow period in readiness for the succeeding cane planting season.

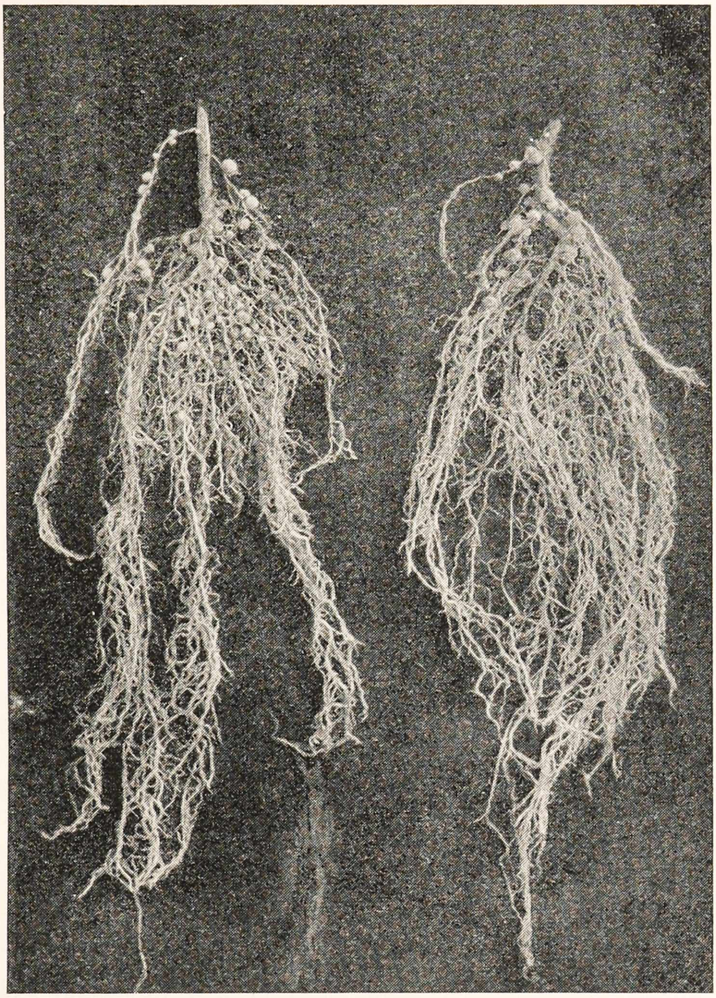

FIG. 14.—Roots of legume showing nodules produced by nitrogen-fixing bacteria.

The crops most usually employed for this purpose are maize, and legumes—such as peas or beans. Though each is capable of producing a heavy mass of green matter in the course of a few months, the weight of values lies with the leguminous crop. Legumes possess the peculiar property of acting as hosts for an interesting class of soil bacteria, which live in small nodules on their roots, and which set up a mutually beneficial relationship throughout their association. In exchange for

the sugars and other foods which the bacteria receive from the green crop, they return a supply of readily available nitrogenous food which they are able to manufacture from the free gaseous nitrogen of the soil atmosphere—a feat which the higher plants are incapable of performing. In this way the equivalent of 200 lb. of nitrogen per acre (equal to 1,000 lb. of sulphate of ammonia) may be supplied to the leguminous crop, and when the green matter is later ploughed under, this represents an absolute net gain to the nitrogen supply of the soil. The maize crop is not able to bestow these benefits upon the land, and for this reason the cultivation of a legume as a cover crop is to be preferred. It should be noted, in passing, that the manufactured nitrogenous compounds are not stored in the root nodules, but permeate the entire plant tissues; the nodules are merely the factories in which the work is carried out by the bacteria.

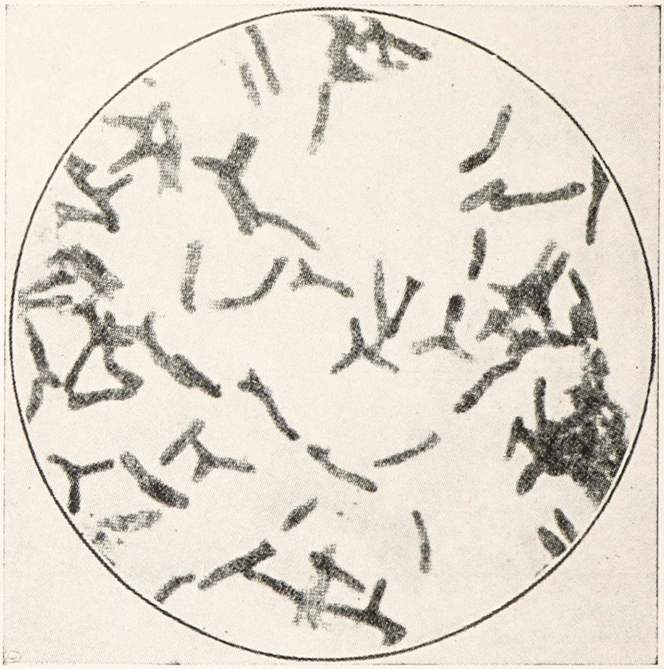

FIG. 15.—Bacteria taken from a root nodule. Magnified about 1,500 times.

A very important factor in the successful growth of a leguminous crop is the selection of a suitable species for the particular set of soil and climatic conditions under consideration. Mauritius bean, cowpea, giant cowpea, rice bean, and Poona pea have all received attention. Mauritius (or velvet) bean is most highly favoured in the Northern districts, while Poona pea has come into favour in recent years in the Central and Southern areas.

The essentials of a satisfactory legume are—(1) that it should germinate and grow even under the adverse conditions which are so frequently associated with early summer weather in Queensland; (2) that it should afford an effective cover in a minimum of time and thus smother the growth of weeds and grasses which are all too ready to establish themselves; (3) that it should be at least tolerant to the attack of the bean fly maggot which so seriously affects late-sown cowpea crops in our coastal areas; and (4) that it shall attain its peak of succulent growth

at a time when it may be conveniently ploughed under. The difficulties which follow the maturing of legume seed are often considerable. Mauritius beans continue to germinate for months after ploughing under, and the vines are very troublesome amongst the growing cane crop. Cowpea is readily controlled, but Poona pea may present some slight difficulties if allowed to mature.

FIG. 16.—Poona pea plants grown in sterilized sand. No. 7 inoculated with a good strain of nitrogen-fixing bacteria, No. 8 medium quality strain, No. 9 not inoculated, and unable to grow due to absence of nitrogen.

It is generally agreed that Mauritius bean is the most suitable where a cover is desired for five or six months. It is not so rapid in its early growth as other species, and may require some cultural assistance to enable it to overcome early weed growth. Poona pea matures in from twelve to fourteen weeks, and is most suitable for short cropping, where the farmer desires to replant his land with cane in the late summer or autumn months. Cowpeas have fallen into disfavour because of their shorter growing period, and the damage caused by the beanfly to most crops planted after October.

During recent years considerable attention has been devoted to the importation of hardy legumes from overseas countries. One objective is to acquire a species which will withstand droughty conditions, such as are frequently experienced in the cane areas during the spring and early summer months. If this could be combined with the virtues of a long growing period—say 4 or 5 months—its usefulness could be exploited on lands which are to be treated to a long fallow. Two such importations have demonstrated distinct promise in this regard: both are species of *Crotolaria* (or "rattle-pods").

The first of these comes from West Africa, and has been called Gambia pea, for convenience. Yield trials show that, under favourable conditions, as much as 25 tons of green matter may be grown during its five months of growth. Moreover, it possesses the power of ratooning if mowed at an appropriate stage in its growth, and it would thus be possible to prolong the green manuring period substantially without

ploughing out or reseeding. It possesses the drawback of rather slow early growth, when grasses and weeds may become established; but thereafter it develops at a very rapid rate, and at times attains a height of over seven feet.

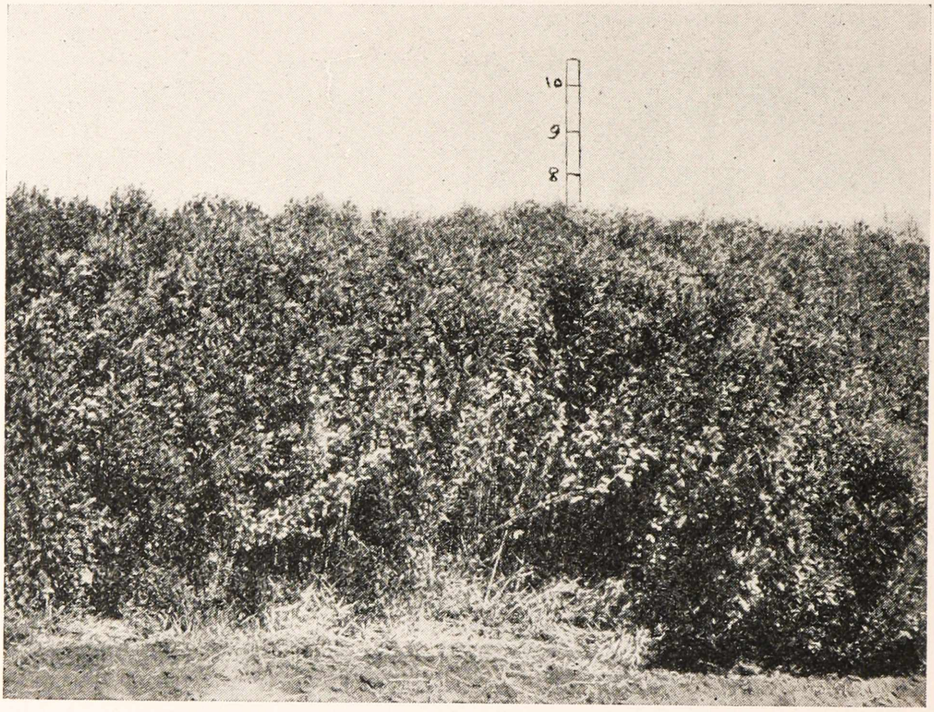

Fig. 17.—An excellent crop of Gambia pea, grown on the Bundaberg Sugar Experiment Station.

The second species mentioned above is the common green manure crop employed on plantations in New Guinea. It has not been tested extensively in Queensland but trials to date suggest that it may possess a definite value as a long-fallow legume.

Fig. 18.—Ploughing under a crop of Gambia pea.

The farmer often wishes to plant a green manure crop in the autumn, for winter growth. This is quite a valuable practice, provided the growth and rotting process do not deplete the soil of moisture which may not be restored by rains prior to the spring planting season. A very successful species for this purpose is the New Zealand blue lupin, which has given excellent results in the Bundaberg area. It provides a heavy mass of succulent plants which do not develop woodiness, even in the stems, and therefore rots readily even during the relatively cool early spring months.

FIG. 19.—Crop of winter grown New Zealand Blue Lupin, Bundaberg Station.

Whatever the crop selected it is found that the greatest benefit from green manuring is experienced if the crop be ploughed under when the seed pods begin to form. At this stage the green mass has attained its maximum growth, and is in a succulent condition. The rotting of such a crop is usually completed in the course of three or four weeks, provided soil moisture is adequate.

A good leguminous crop will add to the soil from 10 to 15 tons of green matter, much of which is moisture. The actual organic matter, being largely of a non-resistant character, does not contribute a great deal to the permanent humus supply of the soil. But the definite gain which is experienced, when taken in conjunction with the undoubted improvement in texture and the gain in fertility which is conferred on the soil, render it a practice of the greatest value to the cane farmer.

Trash Conservation.

The crop residues which remain on the field after the cane has been transferred to the mill offer by far the best possibilities for those growers desirous of effecting a speedy increase in the organic matter supply of the soil. For many years the difficulties of conserving this valuable material where mechanical cultivation methods are employed were responsible for the destruction of large amounts of trash which the grower was reluctant to lose; but the determined efforts of those

enthusiasts who would not be discouraged by these obstacles have succeeded in evolving a plan whereby the trash from all crops may be conserved, and eventually ploughed into the land when the final ratoons have been harvested. Many growers are content to save the trash from the last ratoon crop only; doubtless, this is better than nothing, but when it is considered that the heavier the crop, the larger the volume of organic matter, the desirability of conserving the plant cane trash as well as that from the ratoons need not be stressed. It is sometimes asserted by growers on lands which are productive of very heavy plant crops that the bulk of trash makes the process troublesome. Under these conditions a useful expedient is that of making a "bad burn," when the tops are still quite green, and dealing with the substantial residue in the same manner as will be described for normal practice.

FIG. 20.—The side-delivery rake makes a quick and effective job of trash-rolling.

Considerable thought and energy have been devoted to the invention of a machine which will cut the trash into short lengths which are much easier to handle than the matted bed of material which a newly-harvested field presents. A successful implement was placed on the market some years ago, but it was found that the benefits from the cutting process were slight. The weighted discs which constituted the essential feature of the machine also split the cane stools by their pressure, and this in itself was a drawback. Further, while the heavy bed of chaffed trash allowed the grower to push through with his implements with reasonable ease, it was difficult to keep the line of stools clear, to permit of the rapid germination of the ratoon shoots; and in the event of a cool, wet spring, many of the stools fail to ratoon.

Other growers attempted to plough-under the mass of chaffed trash, and thus eliminate the obstruction which it offered to the progress of the implement work. This again is a practice not to be recommended. Trash is a material which is slow in rotting, due to its peculiarly resistant nature. Though the micro-organisms of the soil will utilize it as a source of food, it does not provide a "balanced diet," and the deficiency in this regard must be contributed in the form of plantfoods

acquired from the soil by the microbes. Now these are the very plant-foods which are much needed by the young ratoons, and if it be denied them, crop growth will suffer. In addition, the turning under of the trash opens up the soil and makes for a rapid loss of soil moisture in hot dry weather, while the rotting process itself is responsible for the dissipation of large amounts of water.

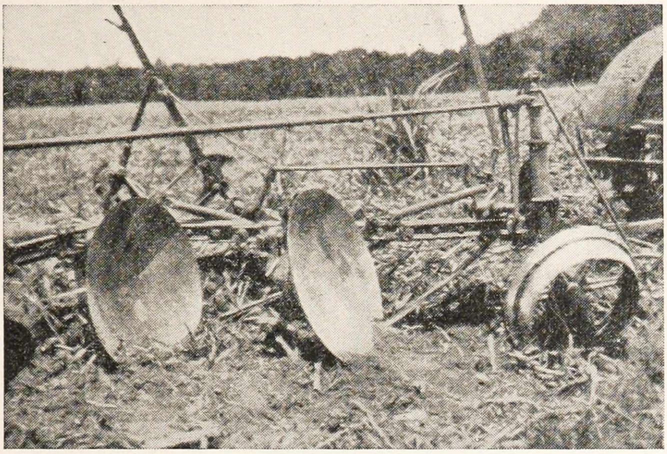

FIG. 21.—Illustrating the use of steel springs as an aid when ploughing-in trash.

It would therefore appear that the trash and tops should be conserved on the surface of the land. This has now come to be regarded as the general method of dealing with it. To permit of the cultivation of the ratoon, which is so essential after the plant cane has been removed, it is customary to transfer the trash from one cane row to the adjacent one, thus leaving the field as a ''grid'' of successively covered and bare strips. In the process, care is taken to bare the stubble and thus allow of the rapid warming up of the adjacent soil which makes for a speedier germination of the dormant eyes. The bared interspace may then be cultivated, while the covered rows will usually remain comparatively free from weeds due to the effective trash mulch. The process of covering the alternative rows with trash does nothing to improve the compacted nature of the soil beneath it; therefore canegrowers who wish to give the land a thorough working follow the practice of moving the trash once more to the cultivated row, where it serves to maintain the tilled soil in good condition throughout the growth of the crop due to its protective influence. Subsequent cultivation operations are then confined to the bared rows.

This method of ''trash rolling,'' as it is called, and which is that usually employed, is the most serious drawback to the wider adoption of the practice. Hand work is slow, tedious, and costly, though there is no doubt that the value of the conserved trash amply repays the grower for his trouble. The recent introduction of the side-delivery rake suggests that with slight modification, this implement will allow the farmer to expedite the work, and reduce the cost to a matter of a few shillings per acre. The standard rake has been designed for handling hay, but the substitution of more robust teeth has made it possible to roll the trash from a 35-ton crop with comparative ease. Another drawback is the loose nature of the pile which it pushes up; this may be compacted by the use of the roller, although an early shower of rain will prevent

scattering of the trash by winds. The rake also permits of rolling three rows of trash into one where the cane crop was light. Where two bare rows alternate with one covered, the employment of grubbers or other tractor implements which straddle the cane row, becomes possible.

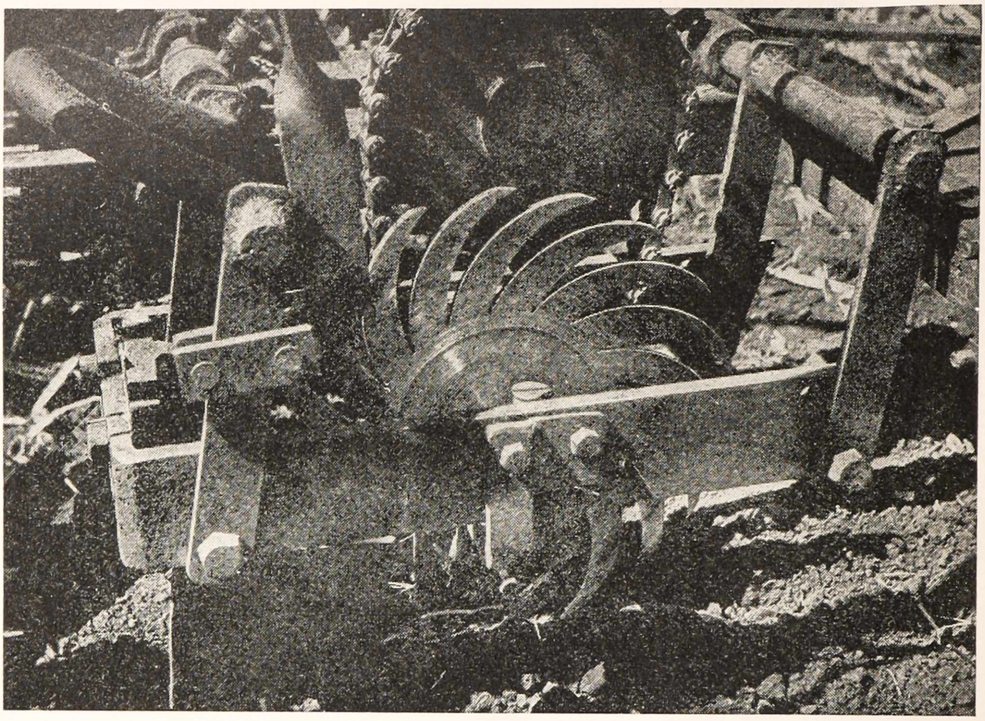

FIG. 22.—Illustrating an ingenious device attached to the plough for facilitating ploughing-in of trash.

By the following harvesting season the bed of trash has lost all its toughness, and due to the process of rotting which takes place even on the surface of the land in hot, wet weather, its mass is greatly reduced. When the succeeding ratoon crop is removed the combined trash residues may be dealt with as already described. Should the condition of the soil below the original trash rows be found favourable, one moving of the fresh trash on to the original rows may suffice.

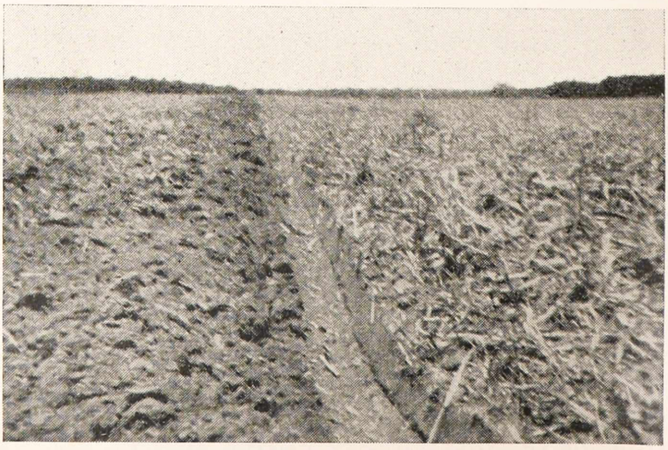

FIG. 23.—Showing the excellent work done with the assistance of the device in Fig. 22.

When the final ratoons have been harvested, all residues remaining on the field should be ploughed under to complete their rotting before the land is again planted to cane. This process was once regarded as a difficult and troublesome one which demanded the use of a plough specially designed for the purpose. But again, the persistent efforts of determined growers have demonstrated that the customary disc plough is capable of giving first class results provided suitable precautions are taken. Firstly, the disc must have a keen cutting edge, and be set as nearly as possible to the vertical. If some device be added which will press down the trash in front of the disc, the latter works well over the material and its cutting action is facilitated. The simplest expedient in this regard is a spring leaf suitably attached to the middle of the plough with the free end pressing on the land surface just in front of the point of contact of the disc. An alternative is a piece of boiler plate which is placed as a horizontal triangular tray beneath the plough, to which it is attached with long bolts fitted with spiral springs. Suitable slots are cut in the plate to accommodate the discs, while the forward projection of the tray is bent upwards to act as a skid and avoid gathering the trash. In action, the plate serves to press down on the trash, and hold it rigidly, while the discs cut it with ease. The degree of pressure is regulated by the strength of the spiral springs.

FIG. 24.—Lucerne is an excellent "rotation" crop, which grows well at Bundaberg with spray irrigation.

A further alternative method which is successful where bulky trash is dealt with lies in splitting the row of stubble by means of a large disc operated at a relatively high speed. A scattering action is thus imparted to the disc, and a reasonably good cover of the trash in the adjacent interspace is effected. As a rule two cuts are made—the first removing one half of the stubble, and the second completing the work of ploughing out.

Which ever method be employed, the land should subsequently be rolled, green manure seed broadcast, and finally disced to provide a fair seed bed and cover the seed. The value of a leguminous crop in the rotation where trash conservation is observed cannot be over-stressed. Trash is notably deficient in the plantfood nitrogen, which is essential to the rapid consumption of organic matter by the soil organisms. This food is provided in large quantities in a successful crop of peas or beans, and when the green material is turned into the land at the peak of its succulent growth, the trash is rapidly decomposed. A highly satisfactory seed bed may be provided for the cane crop in the course of a few weeks, when it will usually be found that all trace of unrotted trash has disappeared.

Farmers frequently express the view that after the trash has served its purpose as a surface mulch, and has lost most of its bulk by decomposition, no appreciable loss is suffered if this small residue is burned. In point of fact, this apparently insignificant residue is the "essence" of the trash in so far as the permanent addition of organic matter is concerned, and it should be guarded jealously.

The benefits of trash conservation may, then, be summarised as follows:—

(1) It provides an excellent mulch for ratoon crops, cooling the land surface and conserving moisture;

(2) It substantially halves the cultivation costs for ratoons;

(3) It provides the only readily accessible source of organic matter the use of which will contribute appreciably to the humus supply of the land.

(4) It enables the farmer to return to the land the entire amount of plantfood contained in the crop residues. Burning of the trash results in the direct loss of the valuable plantfood nitrogen, while the mineral plantfoods of the ash (lime, phosphates, and potash) may be blown from the field unless steps are taken to work it into the surface soil immediately following burning off.

The many arguments which are frequently raised against trash conservation, are probably due in a large measure to failure to continue observations of the cumulative effects of the project over a sufficiently long succession of seasons. A permanent trash trial was laid down on the Bundaberg Sugar Experiment Station in 1933. On the "trash" plots, all crops are harvested in the leaf, and tops and trash are conserved until the final ratoon crop has been harvested, when all crop residues are ploughed under. On the "no trash" plots, the trash and tops are burned after harvest. A study of the comparative yield data for successive harvests shows—

Variety.	Nature of Crop.	Cane Yield Per Acre.	
		"Trash" Plots.	"No trash" plots.
		Tons.	Tons.
Q. 813	Plant ..	36·2	36·2
	1st Ratoon	*9·4	13·1
P.O.J. 2725	Plant ..	19·1	18·6
	1st Ratoon	39·5	34·7

*Du weak ratooning properties of Q.813.

It will thus be observed that any benefits from the treatment were insignificant for the first three years, but the fourth crop shows unmistakable evidence of a cumulative effect, which also appears to be continued in the second ratoons. One may feel certain, moreover, that the slowly acquired improvement in soil productivity will be lasting in its influence, even though the practice should be discontinued.

Finally, trash conservation is not responsible for the rapid increase in the number of insect pests which is usually attributed to the practice. Certainly, the leafy cover affords protection for army worms which are troublesome in certain seasons when their parasites are inactive. But provided the grower takes the reasonable precaution of spreading poison bait when their work is first evident, no loss in crop will be experienced. Trash conservation cannot be regarded as encouraging the incidence of borers, except where conditions are such as to disfavour the drying out of the crop residues. The project similarly must not be regarded as a method of perpetuating cane diseases, except, perhaps, where the crop is infected with downy mildew disease.

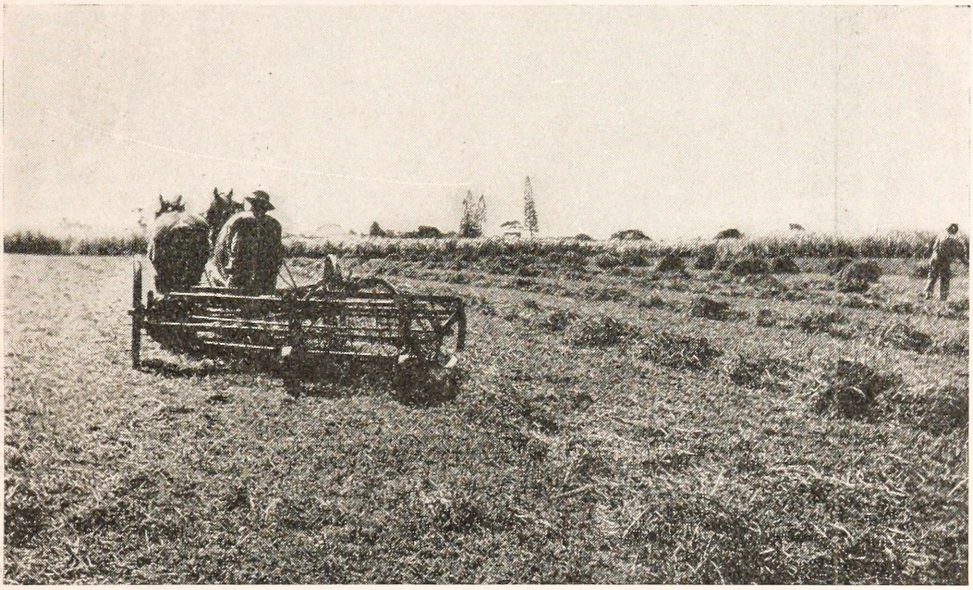

FIG. 25.—By means of the side delivery rake, the harvesting and curing of the lucerne crop is speedily dealt with.

Fallowing.

Probably the simplest method of restoring old cultivated land to a more fertile state is by allowing it to lie in fallow under grass. The benefits of this practice are manifold. Firstly, the land is given a rest from continual cultivation, which helps it to recover something of its original granular structure. Secondly, the plantfoods which are absorbed by the grass crop are eventually restored to the soil once more when it has been consumed by grazing animals and voided as manure. This leads to a continuous system of fertility storage. Thirdly—and this is extremely important from the point of view of the restoration of humus—the mat of grass roots produces those conditions which result in the accumulation of black, humus material, produced by the decomposition of plant remains which are continually being returned to the soil.

Naturally, the benefits to be expected from this policy will be felt only when the system is continued over a period of years. In those cane areas where the farmer is obliged to maintain the entire farm within the four-year canegrowing rotation, no land can be spared for long fallowing. But in the districts of Central and Southern Queensland where the canegrower seldom harvests more than one-half of his cultivable area, the suggestion is worthy of serious consideration. It becomes even more important as more intensive production methods are developed. To harmonise with the yield increases per acre, a smaller area of land need be harvested annually, if the production of excess sugar is to be avoided. It also suggests the possible development of auxiliary crops—notably animal products—which will enable some income to be derived from the land while it is temporarily released from cane production.

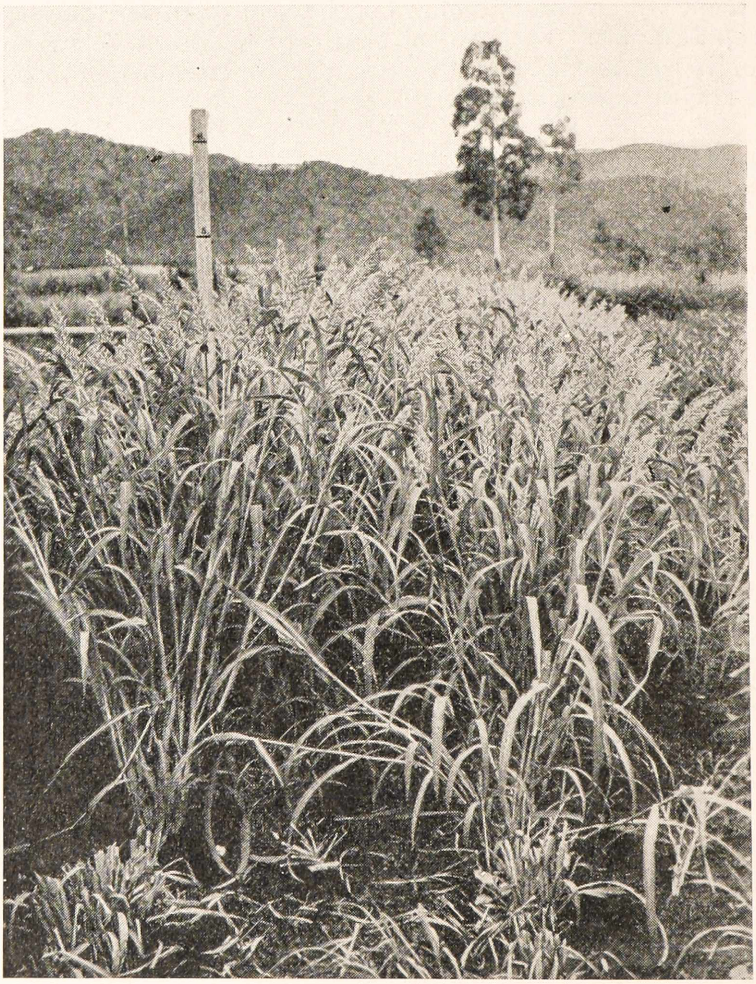

FIG. 26.—A crop of White Panicum, about eight weeks old. It is excellent for fodder purposes. (Grown at the Meringa Sugar Experiment Station.)

By combining green manuring with the practice of fallowing under grass, the process of land renovation may be assisted very materially. A crop of legumes ploughed under prior to seeding with grass will benefit the latter crop, and a further green manuring after the sod has been broken up, will have a marked influence on the yield of the subsequent cane crops.

FIG. 27.—Sheep grazing, as practised at the Mackay Sugar Experiment Station, provides a useful means of deriving income from fallowed land.

For the canegrower whose financial position does not enable him to devote such a sum of money to the purchase of fertilizer as is demanded by the condition of his old cane land, the system outlined is strongly recommended. It is founded on sound agricultural principles, and will speedily restore the land to the level of fertility which will provide the finance required for the acquisition of artificial manures, without which cane growing cannot be remunerative.

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Chapter V.—CULTIVATION OF THE CROP.

PREPARATION OF THE LAND.

When the scrub lands now devoted to the growing of cane were first planted to the crop, the preparatory treatment of the land was relatively simple. The dense vines and undergrowth were cleared with brush hooks, and the heavier timber was felled. When sufficiently dried, the area was "burned off"; after a good burn, only the larger tree trunks and stumps remained, and the cane was planted in rows, the setts being placed in holes prepared with a mattock. With one or two chippings, the crop made, in general, rapid progress, and was soon out of hand. Ratooning was continued with only light surface cultivation with hand implements, until crops became unprofitable. By this time, the tree stumps and logs were generally sufficiently rotted and dried to permit of "grubbing", burning of the heavy timber, and thus leaving the land in readiness for the plough.

Forest lands cannot be treated by the method outlined for scrub-lands; in general, they must be cleared, grubbed, and brought under the plough before the cane crop is planted. The difference in treatment required is related to the condition of the soil in its virgin state; whereas the scrub soil is a condition of excellent tilth due largely to the natural protective covering of jungle, the forest soil has been exposed to a greater or less extent to compacting forces of rainfall and the trampling of animals, and the use of cultural implements is required to produce the mellow seed-bed demanded by the cane crop.

Fig. 28.—A familiar scene when much new scrub land was being brought under cultivation. The setts were planted in holes, dug with a mattock, between the stumps.

After a few years of cultivation, all lands reveal the effects of age, and the canegrower finds it a progressively more difficult matter to produce and maintain those conditions which are most favourable for crop growth. These difficulties are due in part to each of the following

causes:—(1) The cane crop requires intensive cultivation to maintain in the soil those conditions favouring the rapid uptake of moisture, free penetration by its root system, and the stimulus of those soil processes which liberate the essential plantfoods for the nutrition of the crop. Tillage itself tends to destroy the desirable crumby or granular structure which is characteristic of the soil in its virgin state, so that the individual fine soil particles tend to run together readily and become compacted. (2) Intensive tillage promotes free aeration of the soil, which accelerates the rate of decomposition of the soil humus. Though this process is decidedly beneficial to the crop it is a permanent disadvantage insofar as the land is concerned. Humus (see Chapter IV.) is one of the most important constituents of the soil, particularly in its influence on tilth; and the sustained hot, humid conditions of the tropics provide those which make it most difficult to build up and maintain the humus supply of the land. (3) The torrential rains which are rather the rule than the exception in the coastal areas of Queensland serve to drive the soil particles into a compacted mass while the crop is insufficiently advanced to provide a protective covering for the land surface. (4) This compacting action is further assisted by the trampling of man and beast during the growing and harvesting seasons, while the exposure of the consolidated soil to a hot sun and drying winds after harvesting renders it still more difficult to bring the soil back to its friable, mellow condition.

The successful cultivation of cane land is therefore a tedious and costly matter with the majority of Queensland cane soils, and in no other branch of agriculture are these several operations more necessary. In the initial breaking up of the land, after the old ratoon crop has been harvested, the first ploughing serves to cut up and remove the old stubble, and give it an opportunity of decomposing or rotting. At least a further, deeper ploughing is required to break the surface soil to the desired depth. The mellowing process which follows, due to alternate wetting and drying of the soil, is assisted by the action of the harrows or roller, and after at least a further ploughing and harrowing, and following the lapse of at least three or four months with most soils, the land may be in suitable condition for planting the cane.

No hard-and-fast rules can be laid down for the number and nature of the successive operations which are necessary to produce a satisfactory seed-bed for the cane crop; but certain general principles should be observed, and the grower must adapt his procedure to his peculiar local conditions. The discussion of these principles should be studied by the farmer, if he would aim at utilizing the fallowing period to the advantage of the land, and reducing the labours involved in the process of land preparation to a minimum. *Firstly,* it is a mistake to attempt to employ implements as the sole agents for breaking down the soil, and reducing it to a fine granular state. One frequently hears an enumeration of the several operations which a grower has employed to "pulverize" the soil as he so aptly describes it. First the rotary hoe to chop out the stools and reduce the soil clods on which it operates to a state of fine dust; then probably a further disk ploughing, a rolling, and chopping with the disc harrows and plough in an effort to produce a seed-bed in a relatively dry soil, by mechanical means alone. The farmer should understand that one of the finest agents in disintegrating the soil clods in a natural and mild way is the alternate wetting and drying of the land after it is ploughed and left in its initial rough state. The wetting causes the soil to swell, and the shrinkage caused by the subsequent

drying out sets up stresses in the clods which rapidly reduce them to something like the desirable granular structure which is characteristic of a good seed-bed. A pulverized soil is scarcely soil at all; it is dust when dry, mud or slurry when wet, and when again baked dry it is an intractable consolidated cake.

The time factor in soil mellowing is therefore an important one; but again it must be remembered that the action of tropical deluges on bare fallowed land will undo much of the good work that is thus effected; therefore, *secondly,* provide the land with a protective cover crop while the land is out of cane. The most effective method is to plant a suitable leguminous species as soon as possible after the land has been broken up in the spring. Very little special treatment is necessary to get such a crop away to a satisfactory start provided a reasonable amount of soil moisture is available. A rapidly-growing species, such as Poona pea, will soon cover the land, and beneath its leafy protection, even the most difficult soils become friable and mellow. The added benefits which a crop of this nature confer on the land has been discussed under the heading of **Green Manuring** (Chapter IV.).

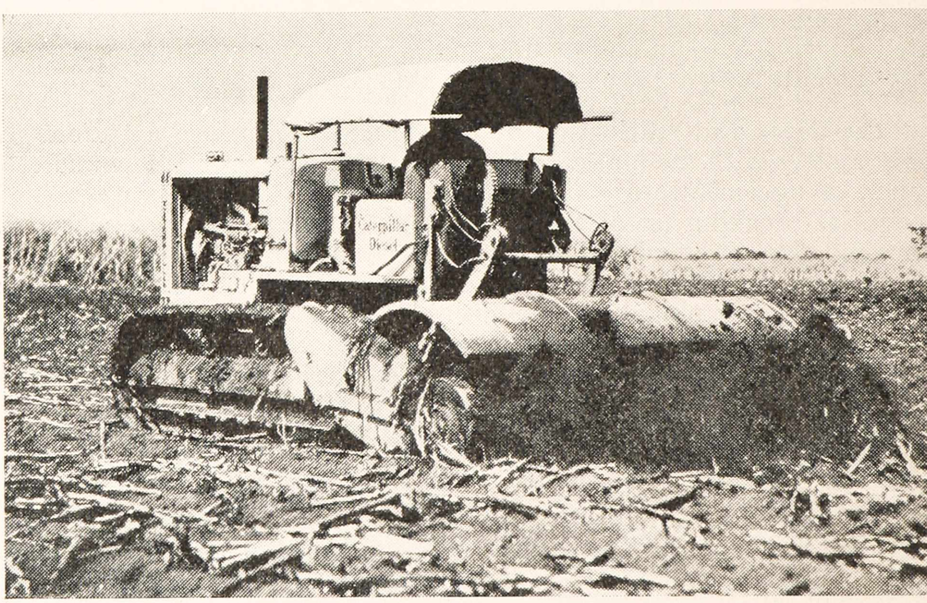


FIG. 29.—The rotary hoe is frequently employed to chop out the old ratoon stubble prior to ploughing.

Thirdly, the soil should, strictly speaking, be worked only at its so-called "optimum" moisture content. This is the condition of the soil when "not too wet or not too dry," when cultural implements pass through it with a minimum of resistance, and produce the maximum of useful results. It is that condition of the soil when, following rain, all visible excess moisture has drained from the soil crumbs. If the soil be worked when the moisture is above this well-defined amount, it becomes puddled, and the ill-effects of a ploughing when the soil is over-moist may take many years to rectify. If the soil be too dry, the ultimate particles are in the form of dust, which is also undesirable.

Now the farmer is not always able to wait for the weather to produce just those desirable soil conditions which have been stipulated, and more often than not the ploughing out of ratoon stubble must

necessarily be done when the soil is hard and dry. It is probably for this reason that the disc plough is so highly favoured by Queensland canegrowers. The mould-board plough cannot be used successfully under these conditions. The best advice for the farmer to follow is to reduce the amount of cultivation to a minimum, when the land is not in its most favourable, moist state. Excessive working at any time is distinctly detrimental to the soil, and to boast that the land was given six ploughings prior to planting is to admit failure to appreciate the essentials of good tillage practice. The land must be thoroughly prepared before planting, but this should be effected through a minimum of cultivation.

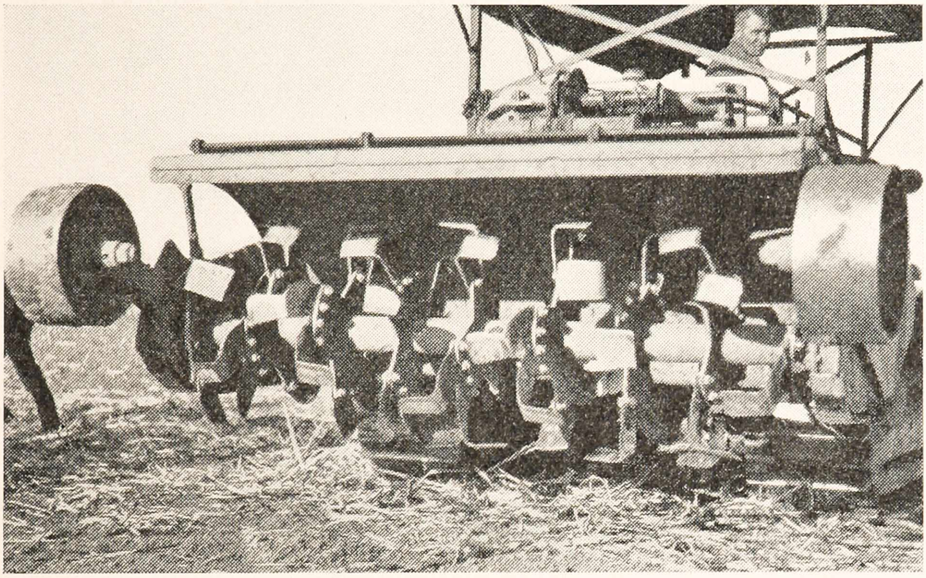


FIG. 30.—Close-up view of the rotary hoe; this is an oversize unit operated by a high powered crawler tractor.

Ploughing.

Cane requires a deep soil, deeply tilled, for best results. It may be assumed that ploughing to a full 10 inches is desirable. Naturally some discretion must be exercised in special circumstances. With deep scrub soils even deeper ploughing is permissible; but where the surface soil is only 6 inches in depth, it is fatal to bring up several inches of raw subsoil to be mixed with the fertile surface soil. Certainly, it is desirable to deepen the tillable soil, but this should be done gradually, and not more than an inch of subsoil should be ploughed up at any one time; this is particularly important where the subsoil is clayey.

Repeated and frequent ploughings to a uniform depth tend to form plough pans in the soil, which frequently become so firmly consolidated that they form a decided obstruction to the penetration of soil moisture and crop roots. When it is remembered that the cane plant demands an abundance of water, and that the only storage which is available during rainy spells is in the surface soil and—perhaps more importantly—the subsoil, the wisdom of maintaining a free and open condition throughout the depth of the land cannot be over-stressed. Where a hard pan exists,

the practice of subsoiling should be followed. By this process, the subsoil is effectively ruptured by the use of an appropriate implement, without bringing any of the raw material to the surface.

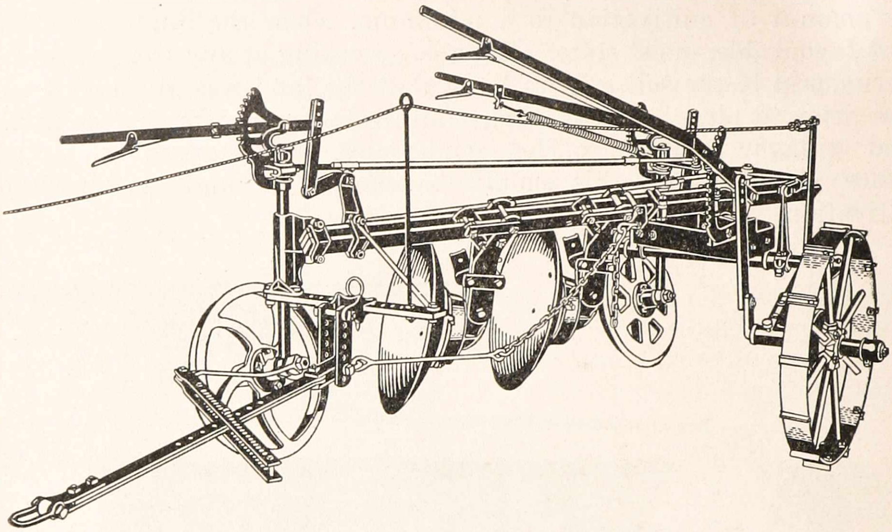


FIG. 31.—A type of two-disc plough which is very useful when ploughing under trash or other organic matter.

This may be effected by the use of modern grubbing implements, where adequate tractor power is available, or by the use of a single subsoiler run in the furrow after the plough, where horses only are employed. In this way a gash 4–6 inches deep, though of no great width, is provided. This allows of the free passage of rain water from the saturated surface soil to the lower depths of the "reservoir" in times of heavy rainfall. It also provides a passage way for the deeply-penetrating water-absorbing roots of the cane crop. Many farmers effect this condition by the use of the skeleton plough; that is, a swing plough from which the mould-board has been removed. It would be found, however, that an efficient subsoiler, provided with a "share" no more than $1\frac{1}{2}$ inches wide, with a knifing standard $\frac{3}{4}$ inch in thickness requires a much smaller tractive force, and allows of a greater depth of penetration.

The question is frequently asked as to whether the mould-board or disc plough is the better. It must be admitted that the shearing action of the former is better for the soil than the cutting action of the disc, but bearing in mind the necessity for working compacted soils in the middle of a dry Queensland spring, the disc must be regarded as the more serviceable. Certainly, there is room for both types of implement, and each should be employed as conditions dictate.

Harrowing.

The plough fractures the soil mass and leaves it in fragments of greater or less dimensions. The implement which is then used to break down the clods is usually the disc harrow, and it is most effective in its work. The tandem discs are commonly employed on cane farms, and are a very valuable aid in preparing the land or in surface cultivation of fallow and ratoon fields. It is also useful when employed on land before ploughing, to cut up trash residues and rubbish before this is turned under.

Lumps are frequently broken by rollers or clod crushers; the roller is also useful in compacting a seed-bed which is too loose and open.

FIG. 32.—The tandem disc harrows assist in breaking down clods.

GENERAL RECOMMENDATIONS.

As a general principle, it is recommended that the preparatory work be commenced in the spring. Land which has been under grass or from which the last ratoon crop has been harvested should be ploughed and harrowed, and green manure seed broadcast. A further harrowing, and

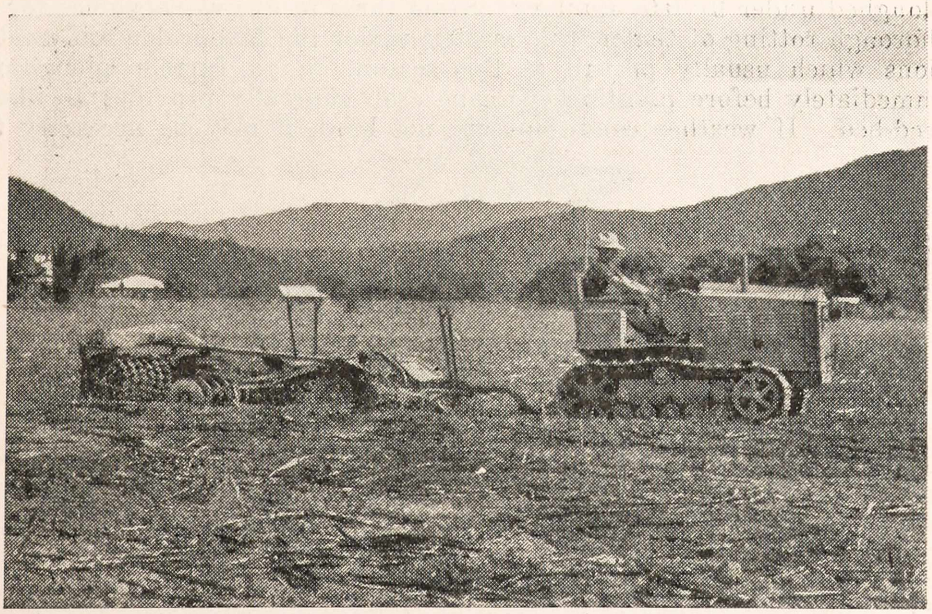


FIG. 33.—The tandem discs operated in conjunction with a clod crusher.

perhaps a rolling, are all that are required, and provided the soil possesses a reasonable degree of moisture, or a shower of rain should fall immediately, a good germination will follow. Of course, the further development of the crop will depend on the incidence of favourable rains, but in general a reasonable growth will be secured in all cane areas. The likelihood of dry spring conditions emphasises the need for breaking up the land as soon as possible after the harvesting, in order to conserve and utilize the available soil moisture to best advantage. With dry weather prevailing, excessive preparatory work on the soil should be avoided, to prevent undue loss of moisture; but if climatic conditions are favourable, it must be remembered that a more completely prepared seed-bed for the green manure crop will make for a better cover, while rendering it a simple matter to prepare the land for the cane crop after the legume has been ploughed under and rotted.

If the land requires liming, it is an advantage to apply this material before sowing the green manure crop; legumes are favoured by an abundance of lime and absence of soil acidity, and a heavier crop will follow.

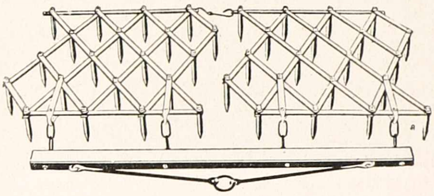


Fig. 34.—The familiar diamond harrows do useful work in preparing cane land.

The leguminous crop which is to be selected as most suitable for a particular set of conditions, requires careful consideration. This is governed largely by the period allowable for the growth of the cover crop. In the southern cane areas of Queensland, for example, where it is generally possible to plant the cane crop in late February or early March, a crop of Poona pea may be grown during the early summer and ploughed under by late January. From three to five weeks suffice for a thorough rotting of the organic matter, under the favourable soil conditions which usually prevail at this season, and a further ploughing immediately before planting the cane crop generally provides an ideal seed-bed. If weather conditions are not kind, it may be necessary to

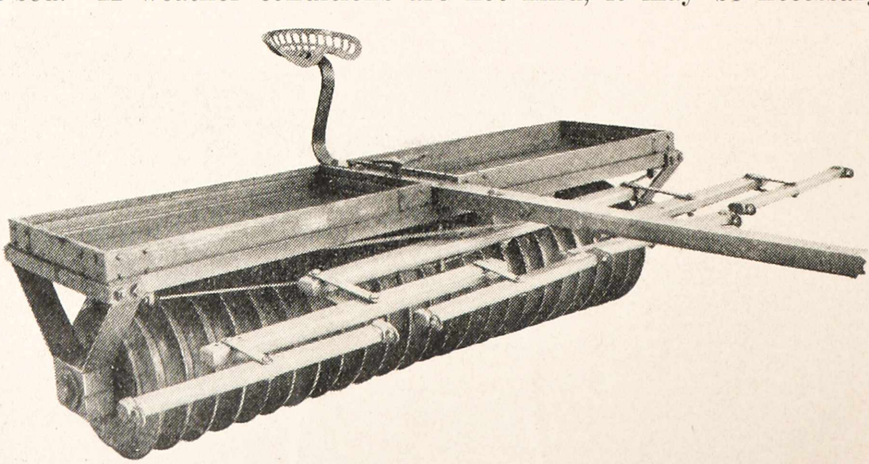


Fig. 35.—One type of clod crusher which may be weighted. It is better to avoid the use of such crushing devices, if at all possible.

defer the planting until the following spring. Where spring planting is adopted, as a standard practice, it is preferable to plant a leguminous species which will grow for from four to six months before maturing. Mauritius beans are probably best for these conditions. In North Queensland, where April-May planting is favoured, Mauritius beans are quite suitable, though Poona pea has received closer attention in recent years.

Spring v. Autumn Plant.

The season at which the cane crop may best be planted is one which has been the subject of much debate. Doubtless, the question can only be answered in a general way, for local conditions often enter to modify practice very materially. On the basis of the evidence available, it is the policy of the Bureau to follow and recommend autumn or "early" planting. Some of the major considerations influencing this decision are:—During the months of February-May the soil is usually well supplied with moisture, and, combined with high soil temperatures, conditions are ideal for a rapid and satisfactory strike. Provided it has been planted sufficiently in advance of the winter, the crop usually undergoes rapid early growth and has completed its stooling in advance of the cool weather. With spring-planting, the farmer is gambling on the prospects of favourable winter rains and warm early spring conditions to ensure a rapid and complete germination of the crop. Under Queensland conditions the risk is rather considerable. Early planting permits of the completion of this important farm operation when the farmer is free from other pressing duties such as are associated with harvesting. The grower is thus able to devote closer attention to his planting than is possible during the spring. Planting of the cane as soon as possible after a leguminous crop has been ploughed under will ensure the absorption of a large proportion of the available plantfoods provided by this practice, before heavy rains have leached away the soluble foods, such as nitrates. This is an important consideration when green manure crops are ploughed under in February-March, and the cane is not planted until August-September.

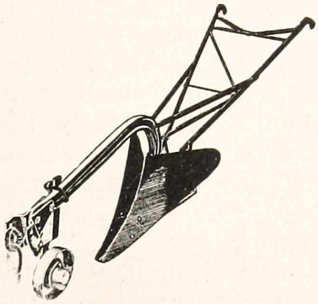


Fig. 36.—The type of drill plough customarily employed when planting.

On the average, it may be assumed that autumn-planted cane will yield 5 tons per acre in excess of a spring-planted crop. It is often claimed that the early planted crop requires more cultivation than rapidly-grown spring cane. Careful examination would probably show that this argument is not in general a sound one; certainly, when due regard is paid to the enhanced crop yield, the more important factor of production costs per ton of cane would show a substantial reduction with the heavier crop. On droughty soils it is claimed that the autumn-plant so seriously depletes the soil moisture supply during a normal

winter in such areas as Mackay that in a dry spring the autumn cane suffers much more seriously than does the spring plant. In areas where frosting is serious, the young crop may be "cut-back" to the ground by cold winter conditions. Though the crop is, doubtless, seriously checked by this factor, it is seldom that the crop is entirely destroyed and in general, the net effect is to produce more vigorous stooling.

It is often found that ratoons following a crop just twelve months old at harvesting time "come away" much more satisfactorily than is the case after an eighteen to twenty months' plant crop. With certain varieties this is definitely a consideration, but with the rapid spread of vigorously-stooling and ratooning canes, this factor is becoming one of minor importance.

Other things being equal, autumn-planted cane will mature earlier than a spring crop. The influence of age on maturity is a very important consideration where no highly satisfactory early-maturing variety is available. Such canes are usually much in demand, but where this cannot be supplied early planting of a normal mid-season cane will assist in providing canes fit to harvest early in the crushing season.

The trend of recent years is towards a higher proportion of autumn planting. Doubtless, the proportion of cane planted at this season in the humid areas of North Queensland would be much greater, but for the difficulty in completing the preparation of the land between the rainy spells of a protracted wet season.

Planting.

The preparatory treatment of the land and the planting operation itself govern, in a large measure, the success of the plant crop of cane. Assuming that the field is in a well-tilled condition, and that full attention has been paid to the provision of a deep, mellow, moist seed bed, the main considerations requiring attention are—(1) the "seed" supply, (2) method of planting, (3) depth of planting, (4) amount of soil cover to apply, (5) application of fertilizers.

"Seed" Supply.—The selection of suitable material from which the plants or seed-pieces are to be taken is a matter of great importance. The canegrower should use only the best available material for this purpose. The cane should be carefully inspected for freedom from disease; or, if it be not possible to obtain a supply free from this objection, those canes which are obviously affected by disease should be rigorously discarded. In general, the selected canes are cut into pieces carrying three sound eyes, placed in bags, and transported to the headland of the block to be planted.

There is often much discussion as to the most suitable crop for the purpose: whether plant cane is superior to ratoons, whether young cane is better than old cane, whether arrowing of the crop influences its germinating qualities, and so on. It may be taken as a reliable guide that well-grown and matured stalks, approximately one year old, provide the best plants. Over-succulent growth should be avoided, in general, and for this reason a well-grown first ratoon crop is frequently preferred to plant cane. Standover (two-year-old) cane should be avoided due to the risk of poor germination of the old eyes.

It will be argued by some growers that they have had most successful results in the face of the above advice. There are seasons of

Fig. 37.—Hand planting was formerly widely practised, but is now largely superseded by the planter.

the year when favourable growing conditions will yield a good strike with practically any class of plant, and greater liberties may be taken in the autumn than in the spring in this regard; but for generally satisfactory results, and the avoidance of failure, the above advice should be followed.

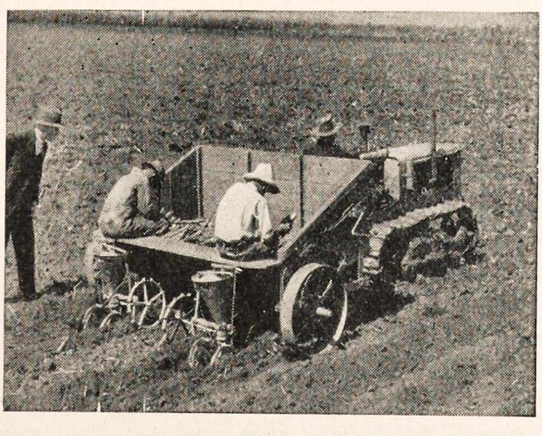


Fig. 38.—A large-size planter which drills out, fertilizes, and plants two rows at a time.

Planting Method.—The planting machine is generally favoured for the purpose of planting the setts in the furrow. This useful labour-saving device is a Queensland invention. Unfortunately, it is frequently abused in practice, and many of the disappointing efforts which are met with are due to failure to appreciate the essentials of good planting. Firstly, growers frequently use the machine for marking out, planting, and covering, in one operation. A machine has recently been devised to cut the plants also. It is highly desirable to be able to perform a maximum of operations in a minimum of time and with a minimum of effort, but this is permissible only where careful attention is given to the individual operations which are combined in the process.

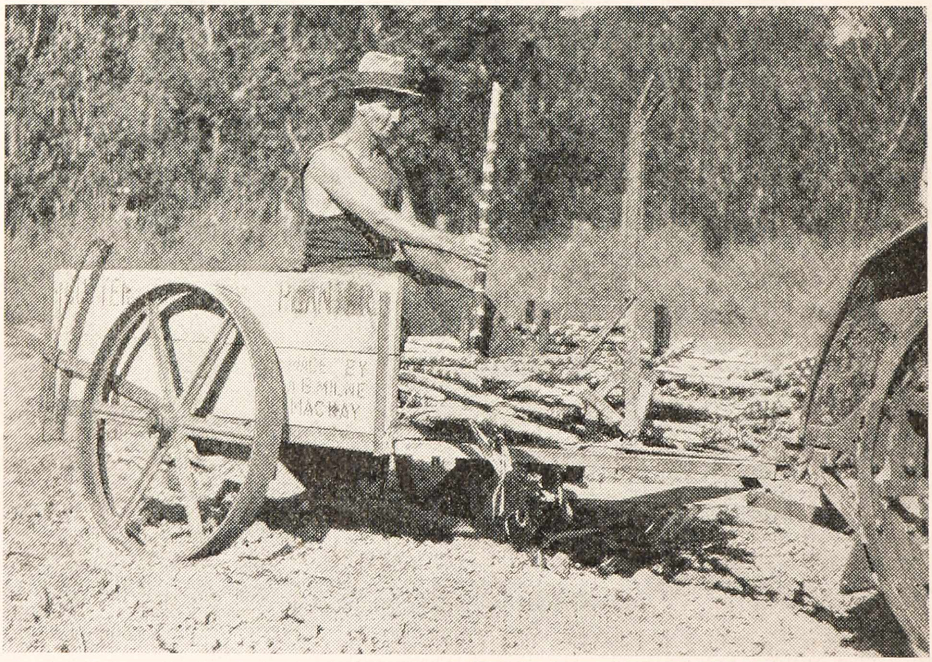


FIG. 39.—One type of cutter-planter; it is fed full stalks which are cut and delivered in the form of setts.

Unless the planter is fitted with a suitable double mould-board attachment to give an adequate planting furrow, this should be made as a separate operation, and a well-designed drill plough employed for the purpose. In droughty areas, it is essential to place the plant at such a depth in the seed-bed that it is surrounded by moist earth which will not dry out rapidly should no rain fall before the crop is established. As a general guide, an attempt should be made to place the seed-piece at a depth of 6 to 8 inches below the *land surface*. This can only be done where a deep, wide furrow is provided, so that the planter may deposit the sett some 2 or 3 inches deeper in the moist earth. The importance of a deep seed-bed is seen in this connection, for it is desirable that the plant be surrounded by mellow soil, and should not rest on the so-called "hard bottom." As was pointed out, this compacted stratum does not favour root development, and where such conditions exist, the young crop is obliged to forego free vertical root penetration, which would assist it to fortify itself against droughty checks.

The number of plants per acre is also a matter on which a wide variation of opinion exists. Our experiments have shown that the spacing of the plants *in the row* may be varied within rather wide limits with but little influence on yield, provided a good strike is obtained. In other words, the number of stalks which will survive on an acre is governed by other considerations than the "thickness of seeding," and it is found that a measure of spacing between setts is better than continuous planting in the row. Spacing leads to the development of a field of well-defined clumps or stools rather than a succession of individual stalks in a row; the larger stools withstand high winds better than those of narrow dimensions, and provide a better foundation for the development of the ratoon crop.

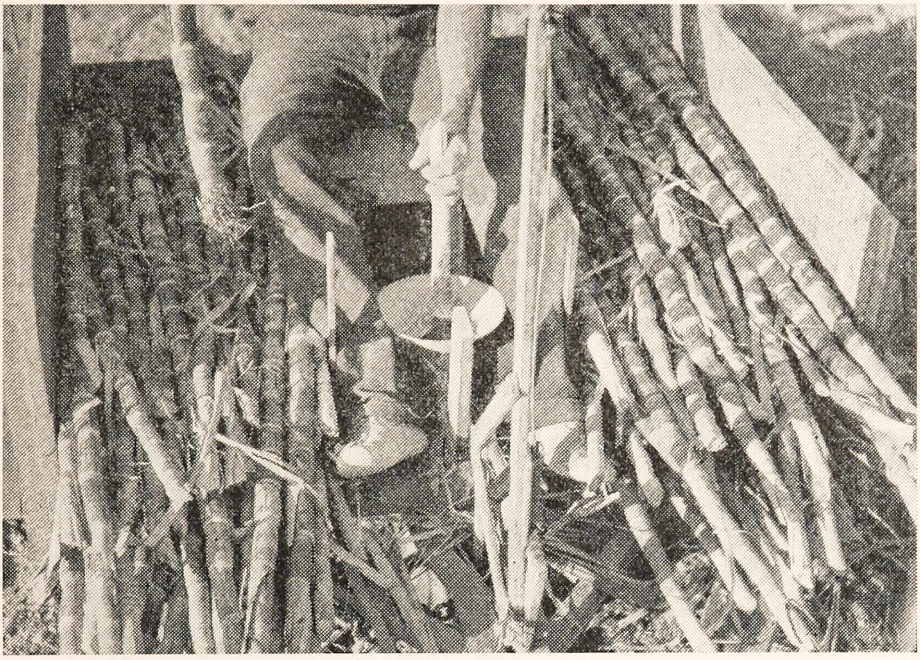


FIG. 40.—Illustrating the manner of feeding sticks to the cutter-planter.

A spacing of from 6 to 12 inches between the ends of successive plants is the customary practice; this will, of course, depend to some extent on the nature of the variety. With the recently introduced Javan canes (such as P.O.J. 2714) with long internodes and consequently fewer "eyes" per acre, the setts should be planted more "thickly" than usual to ensure sufficient shoots per acre for a satisfactory strike. End to end planting is the simplest procedure, under these conditions, but it would probably be better, if practicable, to space the plants as stated above, and place two plants side by side in the furrow. With varieties of poor germinating quality or where even the best available seed supply suggests that a poor strike may result, this latter is a very useful expedient.

Depth of Cover.—The planter may be provided with a device which automatically supplies the necessary earth cover for the setts. With others, it is customary to make this a separate operation, using a scarifier from which all but the two outer tines have been removed. The depth of soil applied is an important factor in the speed of germination of

the setts. Theoretically, the merest trace of soil covering is desired so as to provide maximum warmth from the sun's rays, and thus speed up the process. In practice, the factor of loss of soil moisture must also be considered. Should dry, cool conditions follow planting, the sett may lie dormant in the soil for weeks, and the loss of moisture by evaporation would be serious. The importance of a deep cover, under these conditions, is often unduly stressed. Careful tests have shown that the chief factor governing the moisture supply to the cane sett is its depth below the true land surface and not the depth of cover in the furrow. Under favourable conditions an inch of cover is ample; where the soil is dry, 2 to 3 inches should be the limit.

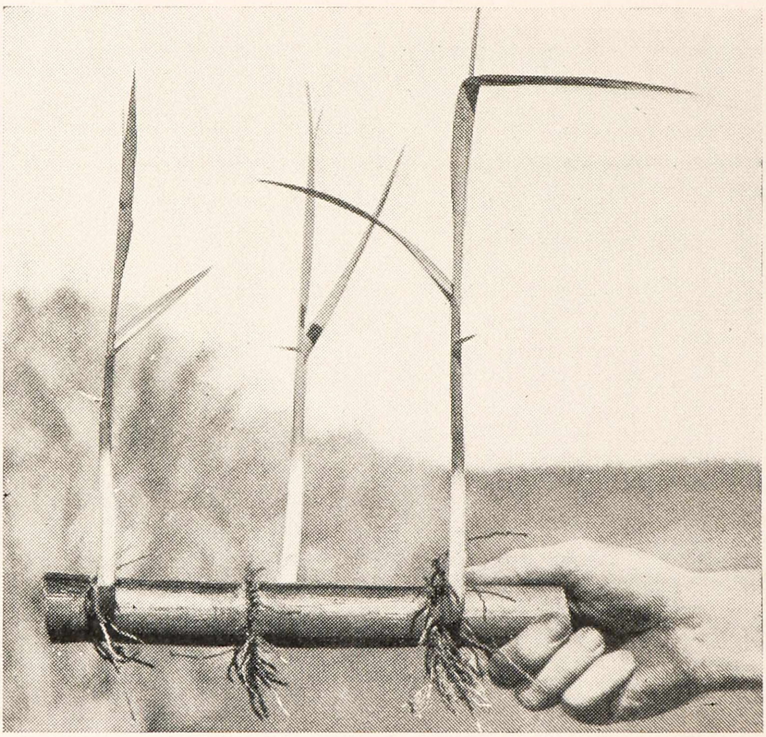


FIG. 41.—Illustrating the manner in which the sett buds or "eyes" and roots develop after planting.

Interspacing of Rows.—The best distance between the cane rows is governed by a number of factors, of which the cane variety is a most important one. The habit of growth of the cane is the characteristic of importance. For a heavy stooling cane of good "covering" capacity (such as Badila), 5 feet between cane rows is generally regarded as a satisfactory standard, and is adopted rather generally in North Queensland. In the Central and Southern areas, 4 feet 6 inches is the customary interspace distance, but it is felt that this is a matter deserving of closer investigation. With varieties very erect in habit, marked success has followed the reduction of the interspace to 4 feet. The major difficulty appears to be that most implements are designed for use with the wider interspace distance.

Application of Fertilizer.—Hitherto nothing has been said of the use of artificial manures, and this important topic will be fully discussed in a later chapter. However, it should be mentioned, in passing, that

the best period for the initial application of artificial manure is at planting time. A suitable mixture should always be on hand at this season, and applied in the furrow below the cane sett. Many modern planters are provided with attachments to take care of this operation.

Hand Planting.—Although in the above discussion it has been assumed that the planting machine is employed, it should be pointed out that it is not intended to discount the practice of hand planting. On the contrary, it has been shown repeatedly that this method, when carried out conscientiously, presents certain advantages over machine planting, and often results in a superior strike and yield. By this method it is possible to watch the operation and thus ensure the uniform dropping of the setts; damage to eyes incurred by running the plants through a machine is also avoided. It is customary for the man engaged in dropping the setts to place his bare foot on each plant, thus ensuring close contact with the surrounding soil particles and promoting better conditions for moisture supply to the sett—a most important consideration in germination and early crop growth.

Supplying.—It is considered that if 90 to 95 per cent. of the setts produce a shoot, the strike is satisfactory. Expressed differently, the strike should be such that few gaps in excess of 2 feet between adjacent shoots can be seen in the block. With careful attention to the several points stressed above, and in the absence of adverse factors over which the grower has no control, this should not present great difficulties. However, where an indifferent stand is obtained, the grower should lose no time in replacing, where necessary, those setts which have failed to germinate; though these later-planted setts will seldom make up the leeway, they do assure a stand and provide for a ratoon block free from excessive gappiness, which leads only to troublesome weed growth and reduced crop yields. Our tests indicate, however, that a stool which produces few stalks in the plant crop will not improve to any extent in the subsequent ratoons.

Cultivation of Plant Cane.

Following planting, nothing further need be done to the field until weed growth demands attention, or until rain falls. Now it is not proposed to specify just how frequently the block should be scarified or what other operations are to be carried out and in what sequence. Again, general principles only will be discussed, and it will be left to the discretion of the grower to determine what implements are best suited to his peculiar conditions. No set formula could be laid down which would fit all areas in all seasons.

It is just as well, in the first instance, to be clear on the purpose of inter-row cultivation of the crop. It was stressed earlier that the purpose of the cultivation operations which are employed in preparing the land for planting were the production of a mellow, moist seed-bed which would favour the early development of the cane; this condition of the land makes for good aeration, so essential to the health and growth of a vigorous root system, and the open condition of the land ensures rapid absorption and penetration of the moisture which falls on the land in the form of rain. It is reasonable to argue, then, that all subsequent cultural operations should aim at conserving these conditions in the soil, and this is indeed one of the chief functions of the systematic tillage which every canegrower knows is essential for

successful crops. One further aspect of this treatment should be stressed. Soil moisture is rapidly lost from a compacted soil by evaporation from the land surface due to the influence of the sun and winds; it has been found, however, that if the uppermost layer of soil be kept in a very loose condition the drying effects may be confined to this layer, and the underlying soil retains the bulk of its moisture for the use of the crop. At the same time the influence of surface cultivation is to remove weeds. It is well recognised by agriculturists that it is not possible to grow any agricultural crop successfully if weeds are allowed to flourish, for they rob the economic plant of the much-needed food and water which are stored in the soil.

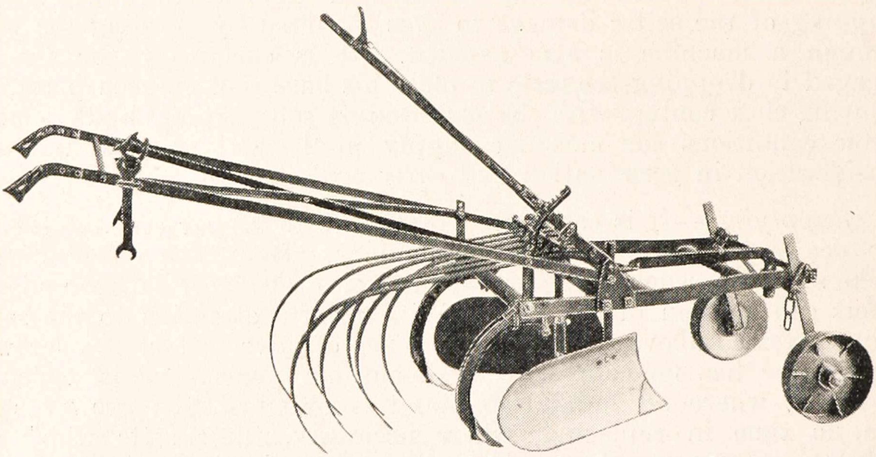


FIG. 42.—The cane cleaner, which removes soil from the furrow and rakes small weeds from the row of cane.

It would therefore appear a simple matter to provide for the needs of the cane crop merely by removing weeds as they appear and loosening the land surface a few days after rain to destroy the surface crust and conserve the soil moisture. Up to a point this is essentially correct, but the process of surface cultivation may itself introduce complications which pass unnoticed unless carefully studied.

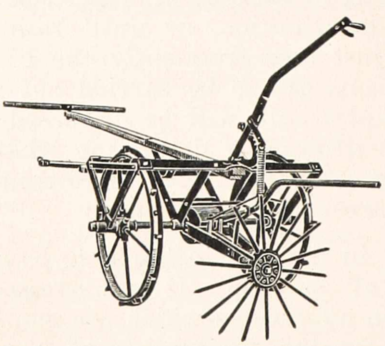


FIG. 43.—The spinner weeder, which is widely used in some areas to remove weeds from the cane row.

Firstly, inter-row cultivation by means of scarifiers or similar implements tends to fill the cane rows. Indeed, many growers purposely strive to assist them in this regard in order to smother the weeds and grass in the furrow. Though this may be temporarily a simple expedient to eliminate chipping costs, the economy is short-lived, for it is found that stooling of the crop can be effected successfully only where

a light layer of soil is maintained in the cane row during the early stages of its growth. Certainly secondary shoots will develop even where rapid filling of the row is allowed, but under these conditions the stool is built up near the surface of the ground, due to the fact that the germination of the lower buds of the root-stock is prevented by the excessive covering of earth. Apparently, the stooling process is affected in some way by the degree of aeration of the neighbouring soil, and where a compacted earth layer seals off the plant from the land surface, stooling is greatly hindered.

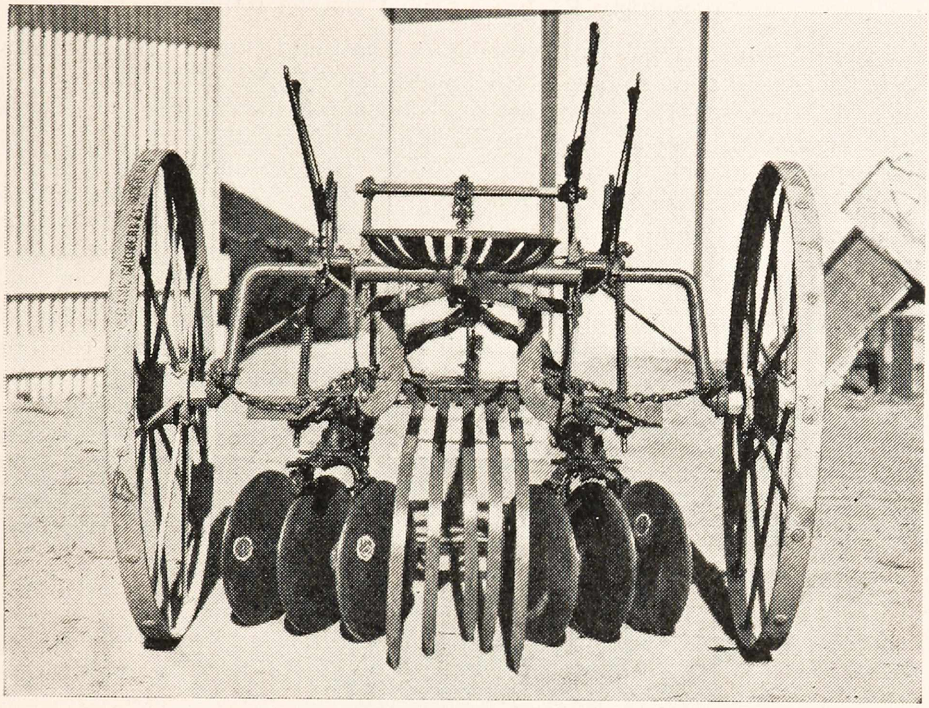


FIG. 44.—A useful type of disc cultivator employed to throw soil away from the young cane, while the rakes remove weeds from the row.

It should, therefore, be the aim of the farmer to keep the cane row open until the cane is stooled, and then gradually fill in as the secondary shoots develop, so as to restore the land eventually to a level state at the time of the final surface working before the crop is "out of hand." Certainly, it is a convenient plan to smother young weeds in the row early in the life of the cane crop; but steps should be taken within a reasonable time to remove the earth once more from the furrow and encourage the stooling of the cane. Chipping is doubtless one of the most tedious and costly operations in the cultivation of the crop, and many methods have been devised for reducing the necessity for this to a minimum. As in all methods of weed control, the secret of success is timeliness of the operation. It is appreciated, of course, that very often weather conditions are against the grower, but it is also true that more often insufficient attention is paid to the importance of early control of weed growth.

A very simple and ingenious device for the removal of the very small weeds from the furrow is known as the "scratcher"; it consists simply of the spring teeth which are usually fitted to the cotton king

or cane cleaner, fitted with a convenient pair of handles, and drawn by one horse. Another useful implement is the cane cleaner itself, which is designed to turn aside the soil from both sides of the cane shoots, while the rake which drags in the row removes the weeds without damaging the young cane plants. A third device which is also useful when the weeds are rather taller is the "spinner." Before the latter is employed it is usual to plough away from the cane with the pony plough, and employ the spinner to remove the ridge of soil (with its weeds) which remains in the furrow. A further implement which is used either to remove earth from the furrow or to "throw on" a little soil, is the disk implement popularly known as the "Cotton King."

Should the grower study carefully the condition of the soil after these several labour-saving implements have been employed he will generally discover the truth of the statement that while implements may be beneficial to the crop, they are often harmful to the soil. Even the homely scarifier is found to compact the soil layers on which it drags, though these effects are not obvious until one removes the surface mulch created. The cane cleaner and cotton king are likewise soil packers, and unless the grower takes steps to correct the compacted condition of the soil which their use creates, the crop roots will suffer from lack of aeration, the beneficial soil bacteria (which will be discussed later) will be hampered in their work, and, above all, the open soil conditions so essential to the rapid absorption of moisture will be lost. This effect is particularly in evidence in times of heavy downpours on lands of even slight slope. The obstruction of the free entry of water results in the rapid saturation of the loose surface mulch, which begins to move down the slope with the run-off water, exposing the tracks of the last tillage implement which was used on the land.

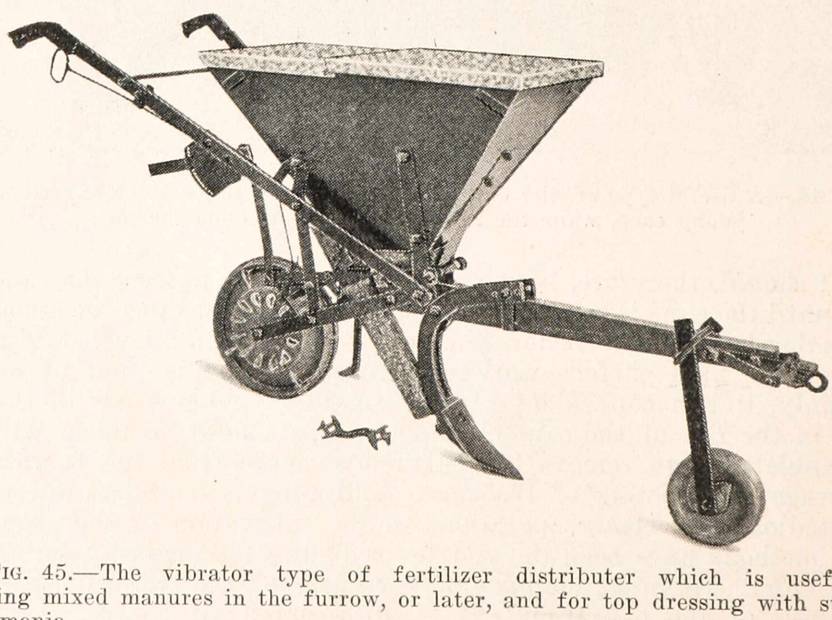


FIG. 45.—The vibrator type of fertilizer distributer which is useful for applying mixed manures in the furrow, or later, and for top dressing with sulphate of ammonia.

The obvious method of overcoming this trouble is to alternate deep with shallow cultivation. Doubtless the grubber is a most useful implement in this connection, provided it is used wisely, and sufficient power is available to allow it to do more than scratch the surface. For the grower who employs only horses, the use of the subsoiler is again

recommended for this purpose. Though it is slower than the power grubber, it does a most effective job. It is often argued that the use of deep tillage implements is detrimental to the crop in that it tears off a number of roots which are of great value to the young cane. Doubtless this is true; indeed, the scarifier is itself a root pruner, but in all cultural operations the grower must weigh the relative merits and demerits of each operation, and provided the beneficial effects

FIG. 46.—Another type of fertilizer distributer which is sometimes employed.

exceed the harmful influences, the operation is justified. Obviously, one would not grub or subsoil during dry weather; the correct time is following rain, when the favourable moist conditions will promote a rapid development of fresh roots to replace those which are torn away. By exercising discretion, the grower will find that the destructive effects of these implements may be minimised by adjusting the distance from the cane row at which the tynes are operating, and this will be governed by the age of the crop or the extent of its root development. The bursting of the centres with a single-tyne subsoiler will result in the shattering of the soil pan to a considerable distance on either side of the gash it cuts, and this is sufficient to improve markedly the ability of the soil to absorb moisture.

Finally, it should be pointed out that nothing is gained by conscientiously stirring the soil in droughty times, when no weeds are in sight or when an effective dry surface mulch has already been provided.

It will be apparent that the early and free use of artificial manures which promote rapid early growth in the crop will ensure a shorter cultivation season and consequently reduced production costs.

When the crop is so developed that the foliage shades the interspace completely, and weeds are thus controlled, further cultivation work is suspended. The crop results will then rest with the weather conditions unless it be on an irrigated farm. Under these latter conditions the control of the crop is very largely in the hands of the grower.

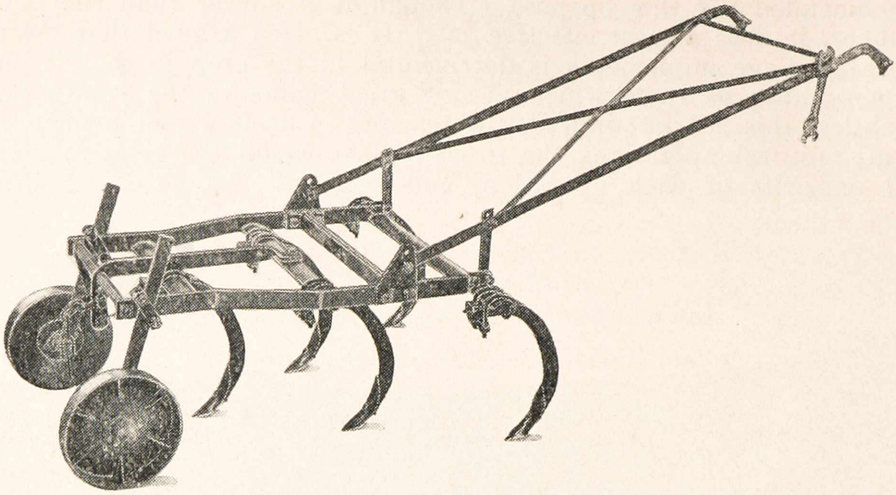


FIG. 47.—After several light cultivations with the scarifier, the horse grubber is a useful implement for deeper tillage. The frame is identical with that used for the cane cleaner. (*See* Fig. 42.)

Ratooning.

Were the grower able to take off only one crop of cane each time the land is planted, the costs of crop production would be very high. However, given suitable conditions, the root stock or stubble quickly sends out a fresh set of young shoots which arise from the dormant eyes of the stubble. Given adequate cultivation, moisture, and plantfood supply, a further crop may be obtained, and often the process may be repeated over a number of years. As it is generally found that the costs of producing successful ratoon crops are much lower than those incurred with plant cane, the success of the industry in any area is closely linked with the ability of the canegrower to produce profitable ratoons.

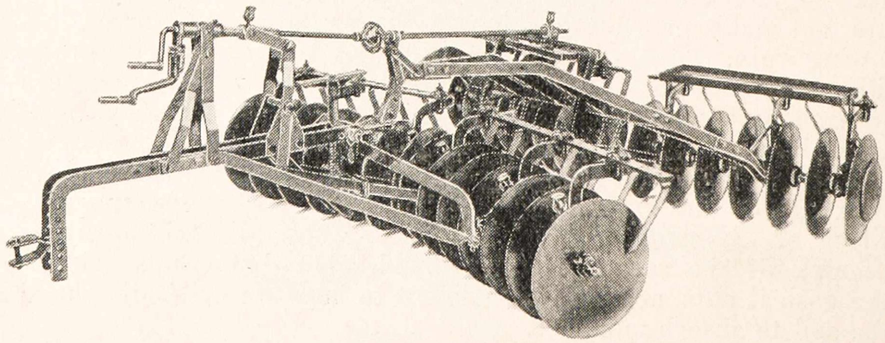


FIG. 48.—The tandem disc harrows are very valuable for preliminary cultivation of ratoon fields.

The care and forethought required in preparing the land and tending the plant crop have already been emphasised; the success of the ratoon is even more closely dependent on the adoption of a cultivation plan in which harmful practices are eliminated, and every advantage is taken of any favourable conditions which exist.

As a rule, the standard practice in ratooning is to await an early opportunity of burning off the crop residues which cover the land. Later, a furrow is ploughed along either side of the row, throwing the soil into the interspace. Following this operation, the "middles" are broken

with the plough or the middle burster, and the whole worked down as well as possible with discs or harrows to provide a reasonably satisfactory medium for the development of the new root system which the ratoon crop must produce for its sustenance. At some stage an application of fertilizer is usually made, to supplement the available plantfood supply of the land which has been heavily drawn upon by the plant crop.

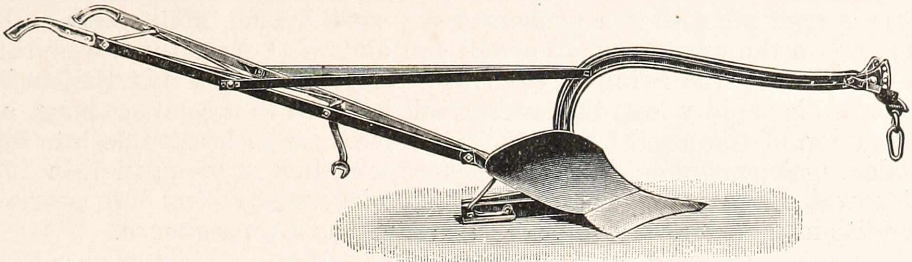


FIG. 49.—The usual type of swing plough employed in the cane field.

Considered in a general way, the ratooning system as outlined is a good one, *provided* that the moisture supply of the soil is adequate, or that rain showers ensure the success of the cultural operations. However, under average Queensland conditions, climatic factors at ratooning time are anything but favourable, and the entire ratooning plan must then be modelled on the absolute need for moisture conservation; nothing should be done which will lead to the undue loss of moisture by evapora-

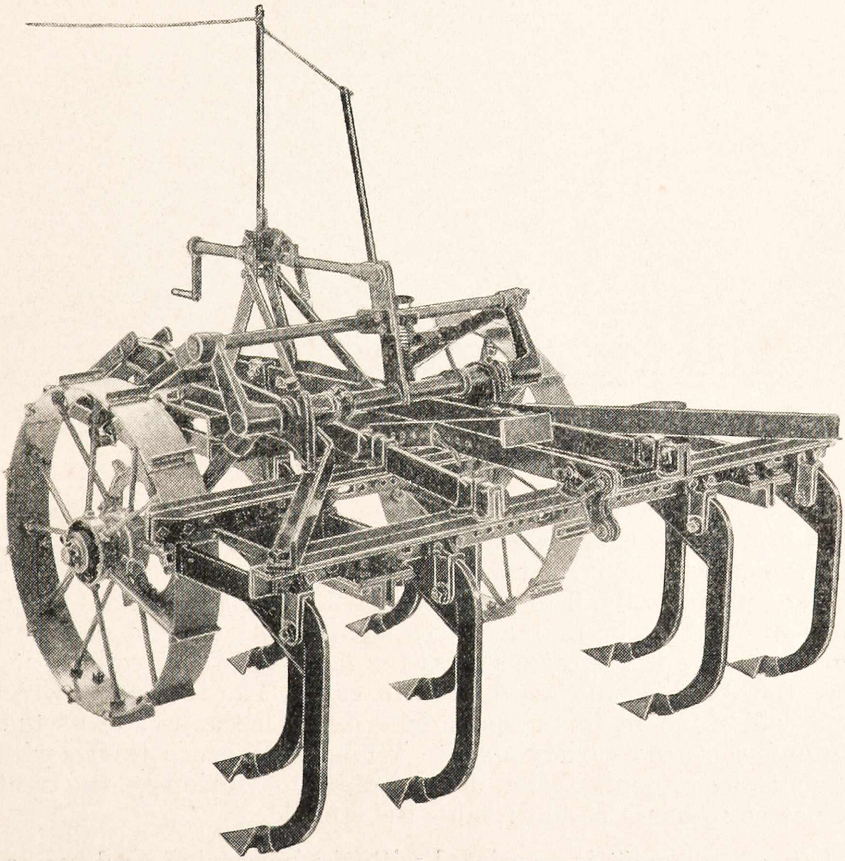


FIG. 50.—The grubber is one of the most useful implements on the cane farm. When adequate tractor power is available, it may be employed for all deep tillage operations, and is excellent for ratooning.

tion from the soil, while at the same time an attempt must be made to restore favourable soil conditions. In order to show how this may be done, the ratooning of a block of old land will be considered in detail, assuming that a customary dry spring is experienced.

If the grower should examine the land surface below a heavy layer of trash and tops, he would find that it is generally in a moist condition. This is true even after a prolonged dry spell. Should the land be left exposed to the drying action of the sun and wind for only two or three days following the firing of the trash, it will be found that the surface moisture is rapidly lost, the surface soil is baked to a compact mass, and the action of the usual cultivation implements is to break this into hard clods which cannot be brought back to a mellow state until rain falls. Meanwhile, the young ratoon crop experiences anything but congenial conditions, and its development must suffer as a consequence.

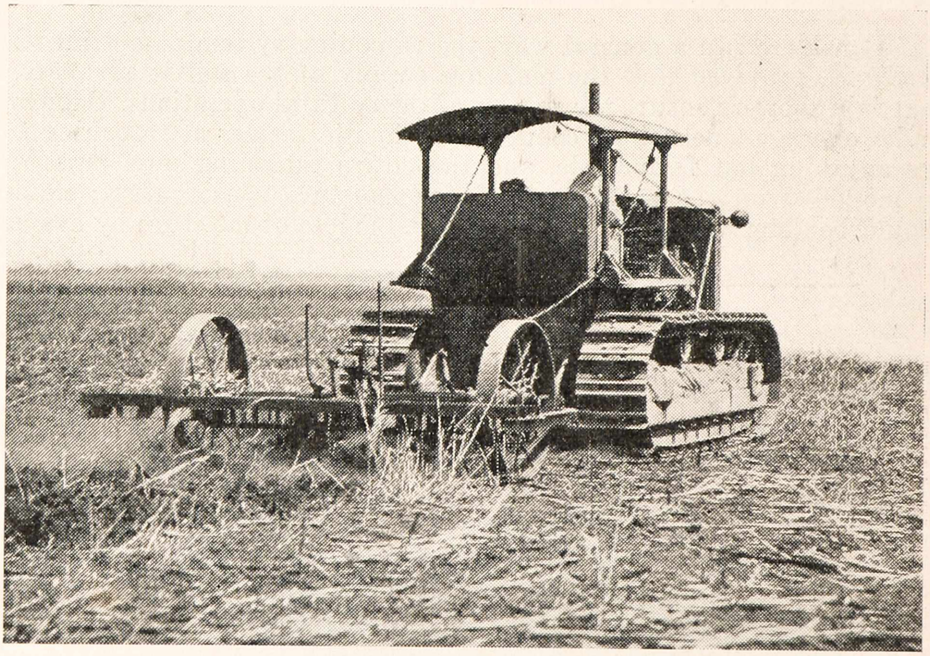


FIG. 51.—Showing the grubber operating in a ratoon field. A large tractor is essential for deep work.

The first point to remember is, then, that the land surface must be worked into a fine mulch *immediately* the trash has been burnt. Alternatively, the grower should not burn off until he knows that he will be able to surface-cultivate the field on the following morning. The most useful implement for this preliminary treatment is the tandem disc harrows. Very frequently it is drawn across the field in two directions at right angles, though this must be done with care. The treatment which the stubble will stand in this respect depends on both the size of the cane stools and the cane variety itself. While some canes thrive with this treatment, shy ratooning canes do not respond. Obviously, the treatment must not be so harsh as to dislodge the stubble.

A further benefit is associated with the harrowing as described. It is usually found that the first eyes of the stubble to produce ratoon shoots are those on the upper ends of the root stock. Even where the

stalk has been cut off some distance above the ground surface, the uppermost eye will germinate. It is evident that the shoots produced in the upper layers of the soil will be obliged, under dry conditions, to develop a root system in the moisture-free soil layer, and this must inevitably fail. Should the upper eyes be destroyed or damaged, the more deeply-set buds produce the ratoon shoots, and by virtue of their position in the moister soil are able to survive. The use of the disc harrows effects this in a reasonably satisfactory manner, and following the treatment it will be found that although the number of primary shoots on a given area is less than is otherwise the case, each is vigorous in growth, and is competent to produce successful secondary shoots; in other words, the ratoons stool in the same manner as did the plant cane. A further benefit from the treatment is that it effectively prevents the tendency of the stool to "come to the top" of the soil, as is the normal behaviour with successive ratoonings. The process is then definitely to be recommended where it is desired to produce a number of ratoon crops.

Fig. 52.—Illustrating the manner in which the ratoon shoots develop after the stubble is treated by disc harrows or the stubble shaver.

Having produced a successful surface mulch, which will effectively conserve the moisture in the land, the grower may proceed with the further cultivation of the ratoon crop as opportunity permits. Should dry conditions persist, the next operation is one for careful consideration. Ploughing away from the stools (or off-barring) results in the removal of a mass of dead roots, and in itself promotes the development of the lower stubble buds by admitting warmth and air; but if in working down the soil subsequently, a mass of dry clods are thrown against the stools, the benefits from the treatment are definitely nullified; and, on the contrary, actual damage may be done should no rain fall. Under these conditions—or under any conditions, for that matter—the best method of ratoon cultivation lies in the use of the grubber. Drawn once or twice in the row—straddling the stools in general—the land may be

broken up effectively to a depth of 8 or 10 inches in a compacted soil. The soil will inevitably be left rather lumpy and open if it be somewhat dry, and no time should be lost in harrowing down to break up lumps and firm the soil.

The final operation of the ratooning process is to apply a dressing of mixed fertilizer. This should be placed where it will be readily utilized by the young ratoon roots. This may be effected by applying the mixture close to the stubble, and at a depth of 3 or 4 inches below the surface. In this connection it should be remembered that fertilizing one side of the row is quite as effective as the two-sided treatment, for a given amount of manure.

Before the ratoons are able to put on vigorous growth beneficial rains are, of course, necessary. Where the method outlined above has been followed closely, soil conditions will be most suitable for the complete absorption of the moisture and the subsequent rapid development of the ratoons. For further cultivation to control weeds, conserve moisture, and maintain the soil in a condition of good tilth, the directions laid down for the plant cane should be followed. When the shoots are about a foot or 18 inches high, a top dressing of sulphate of ammonia should be given. The importance of this will be emphasised when the subject of fertilizers is discussed. Naturally, this manure will be applied following, and not preceding, the elimination of weed growth. Fertilizer is just as beneficial to weeds as to our economic crop.

It should not be necessary to stress the importance of thorough cultivation for successful ratoons. Yet one frequently finds that all the favours in this regard are reserved for the plant crop, and the ratoons are somewhat neglected. The farmer will generally find that it pays to treat the ratoons just as kindly as he does the plant cane. To expect successful crops under indifferent growing conditions is at least unreasonable.

Throughout the above discussion it has been assumed that the crop was passing through a rainless spell in the critical, early stages of its growth. Should, however, the incidence of favourable rains maintain the soil moisture at a suitable level, liberties may be taken with the cultural treatments employed, provided, of course, that the effect of the several operations is to bring the land back to something approaching the deep mellow seed-bed which favoured the plant cane. There is one disability under which the ratoon crop must always labour; whereas it is left to the discretion of the farmer to determine when soil conditions are most favourable for planting his cane, the ratoons must be started on their way as soon as possible after the preceding crop has been removed, irrespective of soil or climatic conditions.

The ratooning quality of the cane is definitely a characteristic of the variety itself. Many varieties—particularly in the central and southern areas—do not ratoon successfully if the mature crop is cut in the cooler months of the year. This is generally true of Q. 813 and Oramboo. Very often the stool "bleeds" after harvesting; that is, the pressure due to the continued absorption of moisture by the roots causes the liquid to flow from the cut ends of the stubble, and the dilute juice begins to ferment. This may completely destroy the vitality of the rootstock, and no ratoons are obtained. The best treatment, where this condition exists, is to remove the trash from the rows as rapidly as possible, thus allowing the warmth of the sun to promote the more rapid germination of the buds on the stubble; and if it be possible to follow the line of

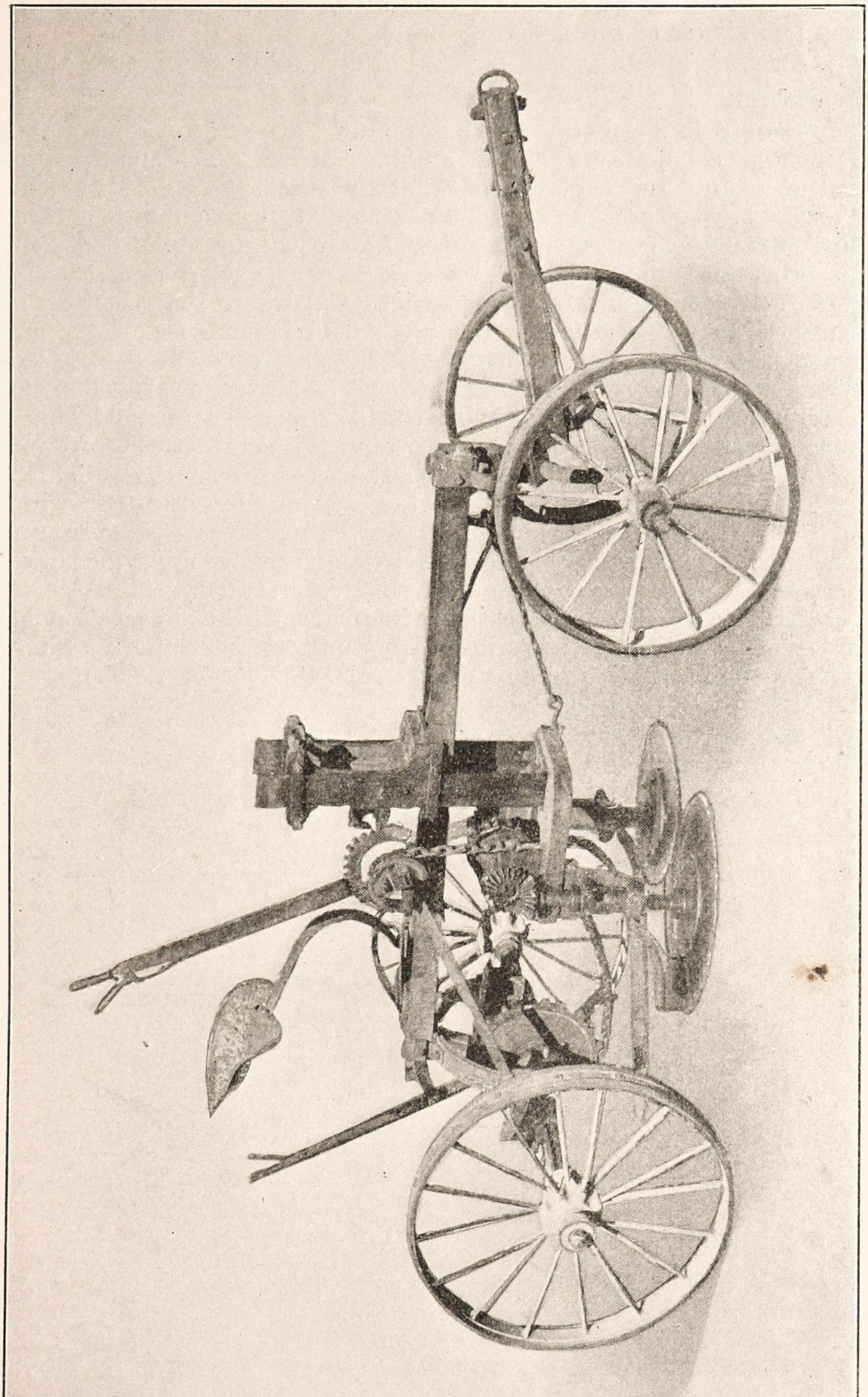


Fig. 53.—Showing the Hawaiian type of stubble shaver which is employed in the Burdekin district.

stools, to plough away from both sides immediately. This destroys many of the moisture-absorbing roots and promotes a more rapid elevation of the temperature of the stubble. Bleeding of the stools is most prevalent where an abundance of soil moisture exists.

Stubble Shaver.

A ratooning implement which has recently attracted the attention of Queensland canegrowers is the stubble shaver. This machine is designed to make a thorough job of what the disc harrows do in their rather crude way—that is, to cut off the stubble below the land surface, and thus effectively prevent the growth of the shoots which normally develop from the topmost buds. This implement must necessarily be employed with discretion, and is only successful where the rootstock is sufficiently large to permit of trimming. The importance of paying special attention to the effective stooling of the plant cane will be recalled in this connection; indeed, successful ratoons under any system depend on the existence of a massive stubble growth to provide the sustenance the young shoots require until they are able to manufacture food for themselves. The implement has been most successful on the irrigated lands of the Burdekin, where under the system of water-furrowing employed, the cane row becomes ridged. The value of the stubble shaver under these conditions is twofold; besides assisting in "keeping the stools in the ground," it also levels the land surface and makes it easier to apply water directly to the cane row after harvesting. The action of the implement is worthy of more intensive study, to determine its place in a system aiming at the growth of several ratoons where at present only one or two may be produced profitably. Its use may be expected to be most successful where the prolifically stooling P.O.J. canes are cultivated.

Chapter VI.—FERTILIZERS AND THEIR USE.

It has been stated (Chapter II.) that the plant absorbs from the soil certain substances or *plantfoods* which are essential for its well-being. In the absence of one of these foods plant life is impossible, while any deficiency in the supply of one or more plantfoods results in unthrifty growth and a proportionate reduction in crop yields.

Most agricultural soils are able to supply the entire needs of the crop with respect to lime, iron, magnesium, and sulphur, though it sometimes happens that supplementary supplies of these substances applied to the soil result in definite crop increases. But most soils—and particularly those which have been cultivated over a period of years—display marked deficiencies with respect to nitrogen, phosphorus (phosphate), and potassium (potash). Additions of the appropriate plantfoods in some form may be accompanied by remarkable yield increases, while it is sometimes found that the productive capacity of the land is doubled by the treatment.

The concentrated forms of plantfood which are used for the purpose of supplementing the supply of the soil are known as *fertilizers.* Although the use of these substances is now almost universal throughout the cane areas of Queensland, there still appears to be some misconception regarding the true nature and function of these materials. It is therefore recommended that the grower study carefully the advice which is here presented; he will then learn that these useful substances are an aid to crop production and an essential to permanent agriculture, and above all, that they are not crop stimulants which will eventually ruin the land.

The simplest forms of fertilizer are those which supply only one of these plantfoods—nitrogen, phosphorus, or potassium. The most important of these are—

Nitrogen Fertilizers.—(*a*) *Nitrate of soda* containing 15 per cent. of nitrogen in the form of nitrate; (*b*) *Sulphate of ammonia,* which contains 20 per cent. of nitrogen in the form of ammonia; (*c*) *Dried blood, cotton seed meal, etc.,* which contain from 6 to 15 per cent. of nitrogen in the form of proteins. While all of these substances are valuable sources of the plantfood—nitrogen—they vary in the speed with which they are available for use by the crop. It is found that most plants absorb their nitrogen from the soil in the form of nitrate. Nitrate of soda is therefore instantaneous in its influence, and may be absorbed by the plant roots immediately it is dissolved in the soil moisture. Ammonia is readily converted to the nitrate form by a certain group of soil bacteria whose particular function it is to carry out this transformation. Sulphate of ammonia is therefore quite readily available, and it may be assumed that, given favourable conditions of soil moisture, the ammonia is completely changed to nitrate within two weeks of its application. The process whereby the nitrogen of dried blood or meal (so-called *organic* nitrogen) is changed to the nitrate form is much more complex, and requires an entire series of distinctive soil organisms to effect its transformation. It is consequently much slower in its action than the soluble "salt" forms already discussed.

In general, however, there is little to choose between all three forms in so far as the ultimate result is concerned; but the grower should

understand that each of these fertilizers must be applied at an appropriate time in the growth period of the crop to attain the desired results. Organic forms of nitrogen must be applied to the soil early in the lifetime of the cane so that they may yield a steady supply of available nitrogen throughout the early months of crop growth. For this reason organic nitrogen is usually embodied in those manures which are used as planting or drill mixtures, and added to the soil at the time of dropping the plants, or at ratooning. Nitrate of soda, on the other hand, should be applied just when it is considered the crop is best able to make immediate use of it. It is therefore customary to employ this material as a top dressing to the surface of the land when the crop roots are sufficiently developed to absorb it when dissolved in the soil moisture. This fertilizer is a most elusive one, and should heavy rains fall immediately following its application, it may be washed completely from the soil before the crop is able to derive benefit from it. Sulphate of ammonia is also used as a top dressing for well-developed crops. While it retains its identity in the soil, it is held quite firmly by the clay particles, and heavy rains will not wash it out; but when it has been converted to the form of nitrate, it is quite as readily removed by leaching as is nitrate of soda.

The question as to which is better for cane farm use—sulphate of ammonia or nitrate of soda—is so frequently asked that it is as well to point out the relative advantages of each:—

(1) On the basis of equal weights of plantfood, sulphate of ammonia is the cheaper material to purchase. As both substances are found to be equally valuable as sources of nitrogen for cane, the grower would naturally prefer the ammonia form.

(2) When stored under humid tropical conditions, nitrate of soda tends to become liquid and frequently the "sweating" is so pronounced that the material leaves the bags. High quality sulphate of ammonia becomes only slightly moist, and though it cakes on subsequent drying it is usually not difficult to pulverize.

(3) Sulphate of ammonia in continuous use tends to make the soil acid. On soils naturally deficient in lime, it is recommended that the land be given, at some stage in the rotation, a weight of agricultural lime equal to that of the sulphate of ammonia that has been employed since the previous lime application. Provided this precaution is taken, sulphate of ammonia will not ruin the land. For soils not deficient in lime, this precaution may not be necessary.

(4) Nitrate of soda tends to destroy soil acidity, and in this respect presents a distinct advantage. On soils in low rainfall areas (e.g., the Burdekin), and with irrigation waters which tend to alkalinity, the use of heavy dressings of nitrate of soda may produce stickiness in the soil and destruction of its granular structure. This effect of soda will be discussed more fully in the chapter dealing with **Irrigation.**

(5) Where fertilizers must be transported over large distances, the more concentrated nature of sulphate of ammonia is definitely a point in its favour; 15 tons of sulphate of ammonia are equal in food value to about 20 tons of nitrate of soda.

Phosphorus Fertilizers.—The chief of this group are—(*a*) *Rock phosphate* (containing 37 per cent. phosphoric acid); (*b*) *superphosphate* (22 per cent. phosphoric acid); (*c*) *basic super,* now *basic phosphate* (17 per cent. phosphoric acid); and (*d*) *bone,* which varies in composition from 19 per cent. to 25 per cent. phosphoric acid.

Rock phosphate is the naturally-occurring form of phosphate manure. The bulk of the Australian supply comes from Nauru Island, in the Pacific Ocean; this deposit is the accumulated residue of guano (bird manure) in association with lime. The material as mined has the appearance of a rather compact rock, and must be ground before it can be employed as a fertilizer. Due to its insoluble nature this form of phosphate produces immediate results only on acid soils, and then only when it is finely pulverised. Ground rock phosphate has not been employed extensively in Queensland, but doubtless it could be used to advantage on many of the phosphate-deficient acid alluvial soils of the humid North.

To convert it to a condition in which it will produce rapid response in crop growth, the natural rock phosphate is treated with sulphuric acid. This has the effect of changing the plantfood to a form in which it will dissolve readily in water. This product is known as *superphosphate,* and is very commonly employed on canelands. When mixed with a proportion of lime, superphosphate is converted to *basic super,* which for many years was greatly favoured by cane farmers. Basic super is somewhat less soluble than superphosphate, but it is nevertheless readily available to the plant.

Experiments have shown that on the basis of weight for weight of plantfood, superphosphate is equally as valuable as the more expensive basic super, and the latter is now seldom employed.

Finely ground *bone* is also a valuable source of phosphate, and large quantities are employed annually in the manufacture of mixed fertilizer. The more slowly reacting nature of bone as compared with superphosphate necessitates its early application to the land (i.e., in the drill), and doubtless its value extends over a series of crops. In general, it will be found that a mixture of bone and superphosphate possesses distinct advantages over either ingredient separately. In the presence of a proportion of moisture, they act on one another with the ultimate conversion of both substances to the basic super form. This may occur either during storage of mixed fertilizers or following their application to a moist soil.

Bone and similar organic manures possess the property of assuring a free-running mixed fertilizer when added to the extent of 25 per cent. or more to mixtures which otherwise tend to set in the bags.

Potassium Fertilizers.—Two well-known forms of potash are employed in Queensland—the sulphate and the muriate. Each carries from 48 to 52 per cent. of potash plantfood, the muriate being usually somewhat the richer. It is claimed that with certain crops muriate of potash is distinctly inferior to sulphate. Repeated experiments with cane lead to the conclusion that muriate is equally as valuable as sulphate; and by virtue of its lower purchase price, its use is to be recommended as far as possible. Muriate of potash possesses the disadvantage of becoming rather moist when stored in a humid atmosphere, particularly when it exists as a mixture with superphosphate. The addition of a reasonable proportion of organic (meatworks) manure will overcome this difficulty, as stated.

MIXED MANURES.

It has been stressed that soils under cultivation become depleted of their available plantfood supply. This deficiency, when it exists,

is usually not confined to one plantfood only, but is common to all three foods—nitrogen, phosphorus, and potash. For this reason it is not customary to employ substances yielding but one plantfood; most frequently mixtures of two or more are prepared in such a manner as to yield a suitable proportion of each of the required plantfoods. It will be appreciated that an endless variety of such mixtures is possible, and the selection of that mixture which is best suited for any particular soil has been the subject of intensive investigation by the Bureau of Sugar Experiment Stations.

The problem may be stated briefly in the following terms:—It may be assumed that a ton of cane must absorb from the soil a certain fixed amount of each of the three plantfoods under discussion. Soils, by virtue of their differing origin differ markedly in their ability to supply these required proportions. Thus, the alluvial soils of the Innisfail area yield large quantities of available potash but are often sadly lacking in their phosphate supply. Doubtless, a mixture suited for this soil type should be rich in phosphates and relatively poor in potash. With the red volcanic lands the converse is true, and for such soils a mixture rich in potash and relatively poorly supplied with phosphate generally gives most profitable returns.

Based on the results of field experiments harvested from selected farms throughout Queensland cane areas, it is found that three distinctive mixed manures are sufficient to provide a reasonable range of selection with respect to the desired proportions of phosphate and potash in cane soil fertilizers. These have been designated "Sugar Bureau" mixtures, and are now marketed by the leading fertilizer distributing companies. Their composition may be summarised as follows:—

Sugar Bureau No. 1 Mixture.—Rich in phosphate, poor in potash.

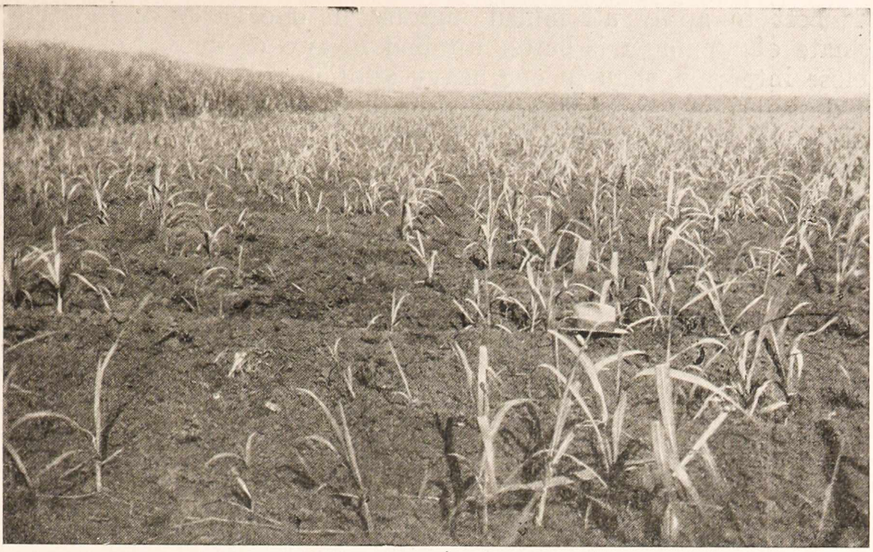
Sugar Bureau No. 2 Mixture.—Relatively balanced proportions of phosphate and potash.

Sugar Bureau No. 3 Mixture.—Poor in phosphate, rich in potash.

It will be observed that in the course of this discussion nothing has been said of the proportion of nitrogen to be included with the prescribed amounts of the remaining plantfoods. This was done purposely to avoid the complications which arise when three variable quantities are introduced into mixtures.

In point of fact, Queensland cane soils are almost without exception deficient in available nitrogen. Moreover, the demand for fertilizers supplying this food varies greatly between plant and ratoon crops; the latter suffer to a much greater extent from nitrogen deficiency than did the preceding plant cane. Finally, it is within the power of the canegrower to provide for the needs of his plant cane without recourse to artificial fertilizers if he follows the practice of ploughing under leguminous green manure crops while the land is in fallow. With the several complications introduced by these factors, combined always with the variable capacity of soils in their unaided state to supply the needs of the crop, it is recommended that the application of nitrogenous manures be regarded as a separate operation from that of the initial mixed-manure dressing.

It has been demonstrated that for best results *early* manuring is preferable to *late* applications. For this reason it is recommended that mixed manures for plant cane be supplied in the furrow with the cane plants; and for ratoons, in a furrow run close to the line of cane



No manure. ⟵ ⟶ Fertilized in drill with phosphate-rich mixture.

FIG. 54.—Illustrating the benefits of applying mixed fertilizer with the cane plants. This soil is phosphate deficient, and the absence of this plantfood on left-hand side of the picture is shown up in the slow and incomplete strike.

stools at ratooning time. If our mixture were rich in soluble nitrogenous fertilizers in addition to the appropriate quotas of phosphate and potash, two difficulties present themselves:—(1) in dry weather the eyes of the plant as well as the young roots and shoots are liable to damage from the soluble nitrogen compounds. This is not nearly so prevalent where the mixtures are confined to phosphates, potash and organic nitrogen materials; (2) excessive rains following planting may leach away the expensive plantfood—nitrogen—before the roots and leaves of the crop are sufficiently developed to absorb and utilize it; and (3), where the green manuring has been carried out, added nitrogen is generally unnecessary.

The Bureau recommends, then, that the necessary proportion of the correct phosphate-potash mixture be applied as suggested for plant cane and ratoons, followed somewhat later by appropriate top dressings of sulphate of ammonia. The need for rather earlier nitrogen for all ratoons has led to the development of two subclasses in each of the Sugar Bureau mixtures already described, to give (*a*) Planting mixtures, (*b*) Ratooning mixtures. The essential difference between the corresponding mixtures is a rather larger proportion of nitrogen in the ratooning fertilizer mixture. For advice in the use of the correct mixture the canegrower should seek the assistance of the local instructor of the Bureau, or the nearest Experiment Station chemist. Where advice has been obtained it is a simple rule to remember that the *number* of the mixture is the important consideration. If No. 1 mixture be recommended, the planting and ratooning variations should be employed for the corresponding crops. In general, a uniform application of mixed fertilizer will be suitable for plant or ratoons, but the weight of sulphate of ammonia applied as subsequent top dressings will require variation.

It is best to apply all mixed manure in one early application, but sulphate of ammonia is better applied in two or more light dressings, at close intervals, than in one heavy application. With plant cane the first dressing of this fertilizer should be applied when the crop is well stooled; with ratoons, the first application should be made when the ratoons are 12-18 inches high, and subsequent dressings at 2 to 4-week intervals depending on the nature of the weather.

FIG. 55.—A simply-constructed fertilizer gun which is employed in Hawaii for applying top dressings of sulphate of ammonia.

The following are the actual compositions of the Sugar Bureau fertilizer mixtures:—

COMPOSITION OF SUGAR BUREAU FERTILIZER MIXTURES.

Mixture.	Nitrogen.		Phosphoric Acid.		Potash (as Muriate
	As Sulphate of Ammonia.	As Bone and Offal.	As Super.	As Bone and Offal.	
	%	%	%	%	%
No. 1 Planting	..	1·0	13·0	4·0	7·5
No. 1 Ratooning	3·0	1·25	9·5	3·5	6·25
No. 2 Planting	..	1·25	9·0	3·75	15·0
No. 2 Ratooning	3·0	1·25	7·0	3·75	12·5
No. 3 Planting	..	1·75	2·5	5·5	25·0
No. 3 Ratooning	3·0	1·5	2·0	4·5	22·5

Farmers should recognise that they are fully protected by law in respect of all fertilizer purchases they make. Regulations prescribe the manner in which the composition of all fertilizers must be declared on the label attached to all sacks, and this is in the nature of a guarantee that the material is up to the declared standard. At the present time, any farmer dealing with a reputable fertilizer firm can then be assured that his purchases are in accordance with the scale of prices fixed for these commodities; his main concern should be to assure himself that he is purchasing the correct mixture required for his particular soil.

As regards methods of applying mixed manure to ratoons, it is found that an application of the full amount on one side of the stool is quite as effective as equal half-dressings on both sides, and the single dressing saves time and labour.

FIG. 56.—Indifferently manured crops are light-yielding, and must generally be burned before harvest.

SOIL FERTILITY TESTING.

Canegrowers are generally acquainted with an important project which the Bureau has pursued for a number of years, for determining the plantfood deficiencies of the major cane soil types of Queensland. This is the scheme of soil fertility determination by recourse to farm plot trials. An area of a selected farm is chosen for the purpose, and subdivided into a number of small plots—each about 1/25 to 1/15 acre in area—on which are applied different mixtures of the plantfood materials—sulphate of ammonia, superphosphate and muriate of potash. From the yield values obtained for the individual plots and treatments, it is possible to estimate just what mixture of fertilizer constituents will provide the best plantfood balance for the particular area.

Though this method must always constitute the most direct and reliable one for the purpose, it will be agreed that the scheme is tedious and time-consuming, and in any year only an extremely small proportion of farms can be dealt with. It is therefore desirable that we should have some simpler method of soil testing by which a reliable forecast of the plantfood position may be gauged speedily and accurately. Recent investigations by the soil chemists of the Bureau have succeeded in establishing reliable methods of this character, and we therefore invite all canegrowers to take full advantage of the soil-testing service and fertilizer recommendations which we can now offer.

FIG. 57.—Harvesting a heavy cane crop which was well supplied with its needs of available plantfood.

There are certain precautions to be taken in respect of the soil-sampling process itself, which we would ask cane farmers to observe very carefully. Failure to do so may lead to erroneous information and misleading advice.

Firstly: Samples should be taken only from fields of plant cane, just prior to or immediately after the harvesting of the plant crop. In other words, samples should be taken between the months of May and October.

Secondly: The sample submitted for test should be truly representative of all sections of the field, to normal plough depth. For this purpose, a posthole digger or auger (for moist soil) will enable the farmer to remove a sample of soil to, say 10 inches deep, allowing one or two borings per acre of land. All borings should be kept and thoroughly mixed before drawing off a final sample of about 2 lb. weight. This should be placed in a clean container, carefully labelled with the farmer's name and address, and despatched to the Brisbane Office of

the Bureau, or to the nearest Sugar Experiment Station. A letter setting out particulars of the field in respect of past history, cropping record, drainage conditions, &c., should also be posted, as this will assist in making a reliable recommendation.

If desired, the local Instructor in Cane Culture or Field Officer will actually take the necessary samples on request, and attend to all necessary details. This is a service of which all cane farmers should fully avail themselves.

Chapter VII.—IRRIGATION AND DRAINAGE.

INTRODUCTION.

In Chapter III. emphasis was laid on the importance of the soil moisture as a factor in crop growth, and the necessity for conserving all available moisture which reaches the land surface in times of rain, to sustain the crop during dry spells. In Queensland these droughty periods occur with decided frequency, even in those areas where the total annual rainfall exceeds 80 inches, while the heavy rainfall areas of our coast are by no means free from their influence. As every growth check which the crop receives may be measured in terms of crop losses, it is natural that the canegrower should give consideration to the possibility of their elimination, by the artificial application of water. Indeed the most successful canegrowing regions of the world are those which are able to maintain as nearly as practicable continuous crop growth, by the aid of irrigation.

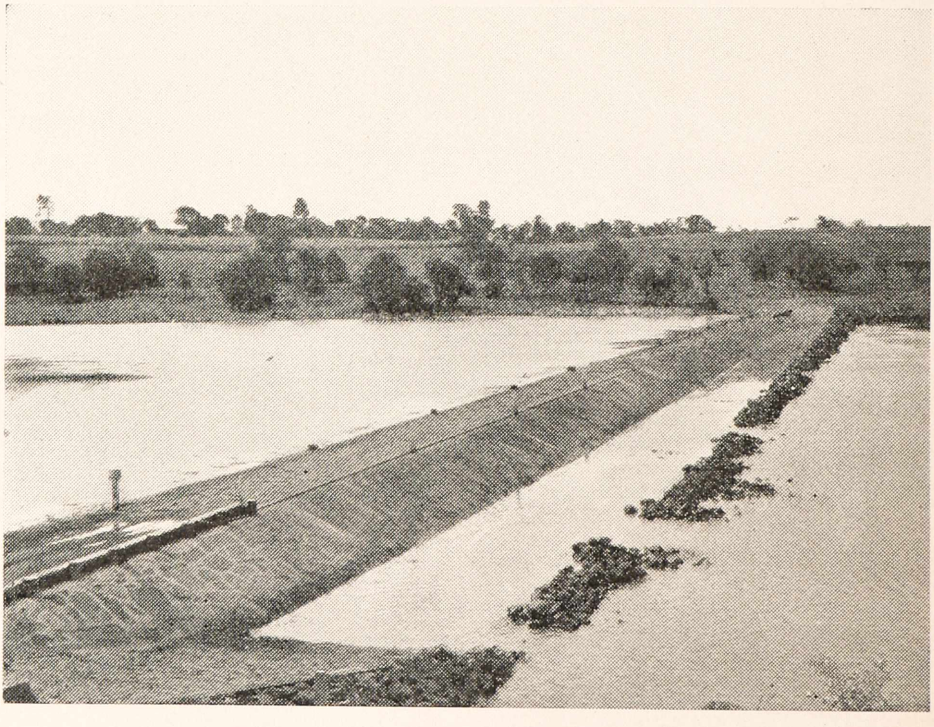


Fig. 58.—"Water is the life-blood of the cane crop." Weir across the Burnett River at Bingera, to provide storage for irrigation water.

In Queensland the Burdekin area is the only one in which this is standard practice, for canegrowers there have learned that this is the only way in which the alluvial lands of the district may produce those crops which their natural fertility promises. This district enjoys the distinction of producing consistently heavier tonnages of cane per acre than any other area in Queensland; and although irrigation adds to the costs of production on an acreage basis, it is also true that, given an adequate and suitable water supply, the costs per ton of cane may be substantially lower than those in many unirrigated areas. In a country of high labour costs, irrigation practice in canegrowing provides one of

the most valuable means of promoting a high labour efficiency and an assured crop.

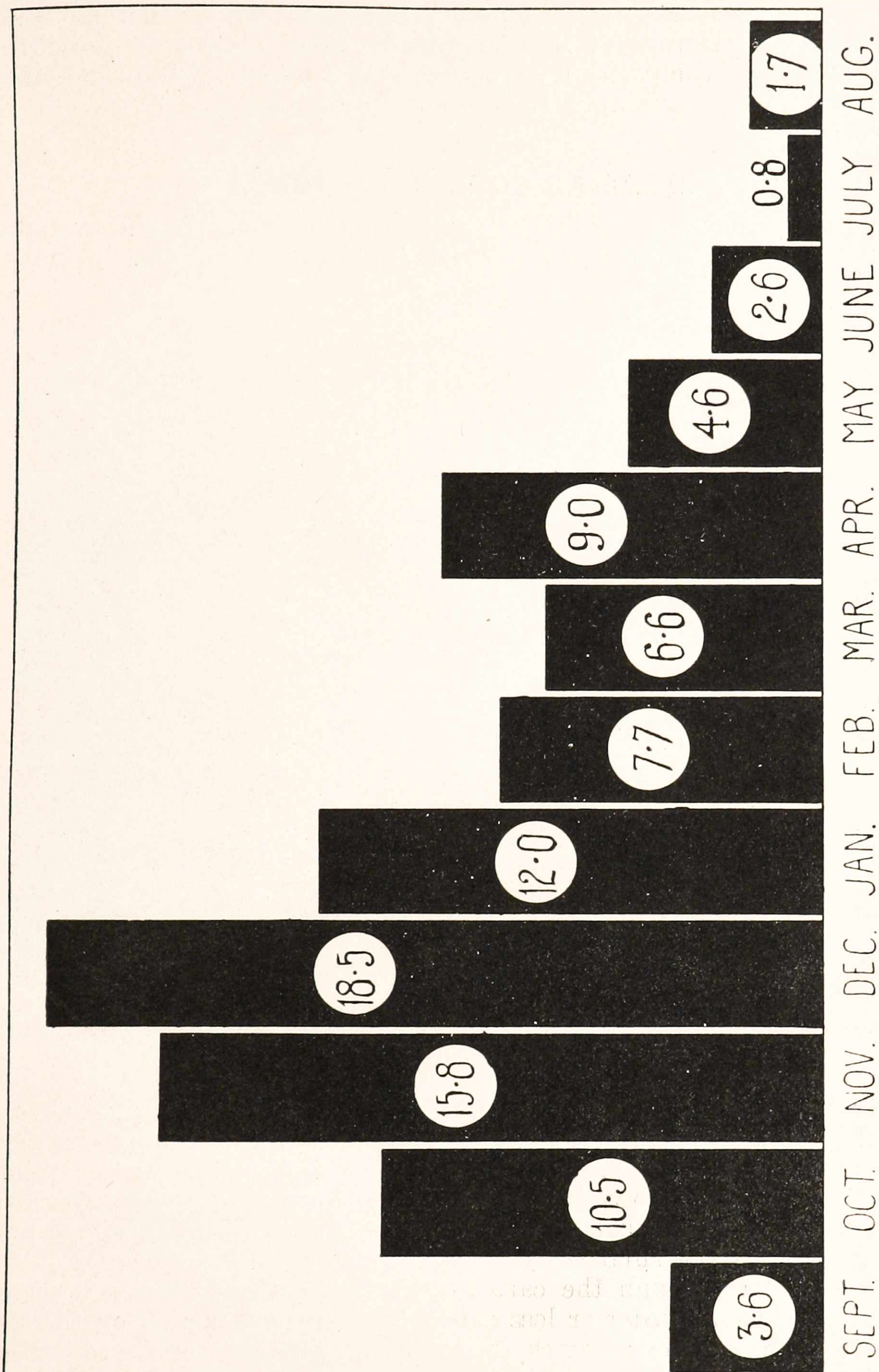


FIG. 59.—The figures in the circles show the cane tonnages produced during the respective months, where the crop lacked neither moisture nor plantfoods. The actual yield was 93.4 tons of cane per acre.

Some interesting experiments have been conducted by the Bureau in recent years to determine the influence of soil moisture supply on cane growth. At the South Johnstone and Bundaberg Stations crops have been grown under a system of weekly waterings, which would ensure an abundance of available moisture throughout their lifetime. Under these highly favourable conditions, yields were greatly in excess of

anything experienced with normal farm practice. At Bundaberg, for example, a plant crop of P.O.J. 2878 yielded 93 tons of cane per acre, and the first ratoons gave 75 tons. While it is agreed that no cane-grower aspires to crops of this magnitude, these figures do provide a useful basis for comparison of *actual* and *possible* yields, and they demonstrate very strikingly the importance of unchecked growth on acreage returns.

GENERAL CONSIDERATIONS.

While the principles of irrigation are essentially simple and straightforward, there are several points which the farmer must clearly understand in order that he may avoid disappointment.

FIG. 60.—An excellent crop of sugar cane (with young ratoons in the foreground), produced in the Burdekin district by irrigation.

First of all, it must be realised that irrigation water differs from natural rainfall. The latter is essentially Nature's own pure distilled water, until the moment it reaches the earth. Thence the surplus either runs off and finds its way into natural watercourses or percolates into the depth of the porous subsoil strata, where it may again be tapped and brought back to the surface by artificial means. In the course of its passage over or through the earth, the originally pure water becomes contaminated to a greater or less extent by its solvent action on the soil particles with which it comes in contact. Though certain of these substances—notably calcium (lime) compounds—are distinctly valuable to the soil, should the water be employed for irrigation purposes, there are others which definitely detract from the quality of the water. These are—excessive salt and carbonate of soda. It is therefore most desirable to have an analysis made of any water supply intended for irrigation purposes. The amounts of these compounds in the soil which can be tolerated without harmful effects depends to a large extent on the nature of the soil. Certain alluvial lands become sticky and difficult

to work if treated with water containing even a few grains of carbonate of soda per gallon, while salt accumulations lead to crop damage on all types of soil where subsoil drainage is defective. Fortunately, the majority of the subterranean waters of our coast, and practically all open streams not subject to tidal influences, are suitable for cane irrigation purposes.

A second consideration is the adequacy of the supply. It has been stressed that cane is a water-loving plant, and the supplementing of the natural rainfall under average Queensland conditions will demand at least 40 acre-inches of water per annum to maintain unchecked crop growth. In round numbers, this means 1,000,000 gallons of water per acre, or, for 40 acres of cultivation, 40,000,000 gallons a year. To carry the calculation a little further, we will assume that the application of this amount of water is spread over 100 days. The average daily consumption will then be 400,000 gallons, or 40,000 gallons per hour for a 10-hour day. These figures show the extreme importance of an adequate water supply before the project is embarked on. When pumping from small streams the farmer must also remember that October and November are the driest months of the year, when the irrigation supply will be in greatest demand. By the same token, the flow of natural watercourses is also at its lowest ebb during this season. In making a survey of streams of limited capacity it should therefore be remembered that estimates should be made at this period of the year.

Testing of the Supply.

The testing of underground supplies is not so simple. Some indication may be gained by a pumping test on a bore which has been driven into the water-bearing stratum. When boring, it is customary to operate the auger, sand pump, etc., inside a steel casing somewhat larger in cross sectional area than the tool which is employed. By applying weights or force to the casing, it is driven downwards as the soil or sand is removed from within. Successive lengths of casing are attached to enable it to extend to the water-bearing stratum; for preference, the casing should be lowered to the *bottom* of this layer. For the pumping test, a "spear" attached to a suitable suction pipe is then lowered within the casing, and attached to a pump. The spear consists of a cylinder of gauze which serves to admit the water while excluding the sand. Modern spears are now manufactured as variations of the earlier type, but they perform essentially the same task with greater or less efficiency.

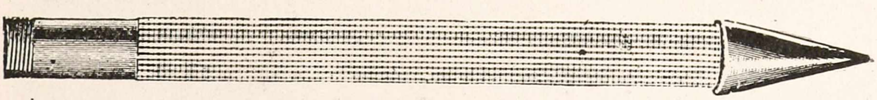


FIG. 61.—Illustrating the old style gauze-covered spear.

The nature of the test pumping unit is a matter for consideration. A centrifugal or other form of suction pump cannot be operated unless located at not more than 25 feet above the water level; the level will, of course, also be lowered during the progress of the trial.

Naturally, the capacity of a single bore may not provide a true reflex of the full capacity of the water beds. A number of factors enter to complicate the problem. If the water-bearing stratum, or "drift"

as it is called, is of very coarse sand or gravel, it will offer little resistance to the free passage of water, and it may be possible to draw a large supply from a single bore. On the other hand, a fine sand drift may yield water at a relatively slow rate, yet with a series of spears,

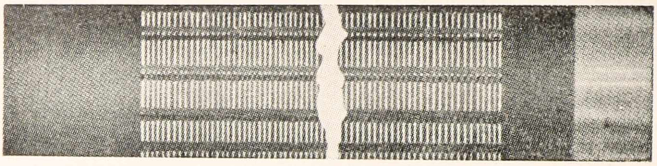


FIG. 62.—A new-type spear which consists of a slotted metal cylinder.

each suitably located, and jointed to one central suction pipe, it may supply over 100,000 gallons of water per hour. These questions require careful study and test in order that the true capabilities of the site may be gauged. Of course, expert advice is very helpful and necessary in reaching a reliable conclusion in these matters.

Distribution of Water.

Assuming that an adequate supply of water is available, the next consideration is that of its application to the land. With natural precipitation, the even distribution of the water is automatically taken care of; but when water is applied artificially, this can only be effected when considerable care is exercised. Irregularities in the land surface are frequently present and complicate the problem, while even under the most favourable conditions the supply of water to the margin of the

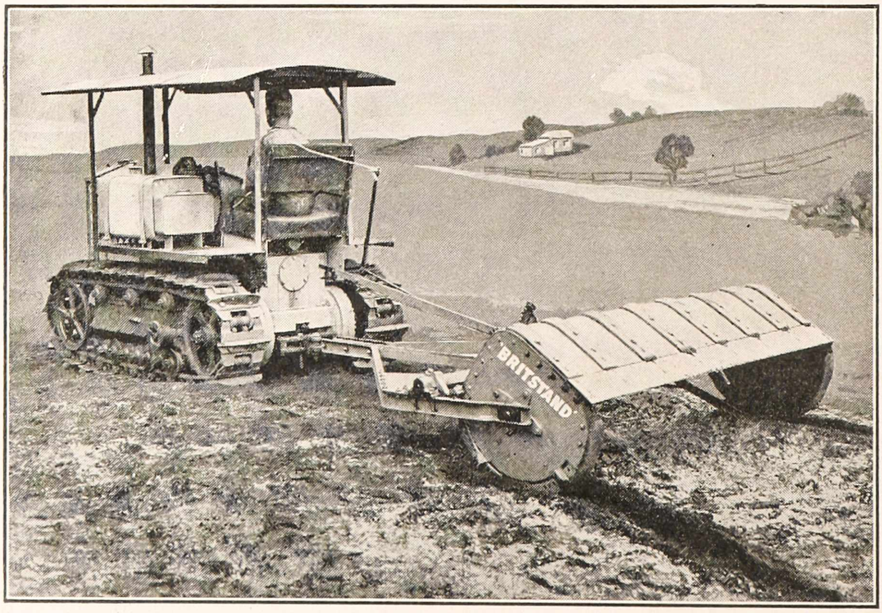


FIG. 63.—The tractor-operated automatic scoop makes a quick job of land grading.

field where the water enters is inevitably greater than at the distant end of the water furrows. A judicious grading of the surface soil will often serve to provide even grades, and simplify the job; but this must be done with discretion to avoid the removal of the entire depth of

surface soil, exposing the infertile subsoil. In general, a good depth of surface soil must be available before this project is attempted. To prevent gross irregularities in water distribution as between opposite ends of a field, the length of the water furrows must be restricted. Many farmers attempt to run the water 15 chains or more in the furrows; under these conditions, the near border of the block may receive 12 inches at one watering, while the distant end may get less than two. Not only does this lead to a tremendous wastage of water, with a consequent increase in watering costs, but the danger of water-logging the soil and damaging both soil and crop exists where the subsoil is not porous in character.

The most favourable length of furrow will depend on both the soil type and the gradient of the land surface. Light-textured soils (sandy loams) require short furrows to avoid excessive seepage losses, while a gradient of 2 or 3 per cent. will, in general, permit of a longer water-furrow than will relatively level land. It may be concluded that furrows from 3 to 5 chains in length will lead to the most favourable results. The water saving which will be effected, and the consequently increased speed with which the entire farm may be irrigated will usually outweigh any apparent saving in labour costs which is claimed for the long-furrow system. Where the water supply is limited, any policy which leads to water economy is worthy of the most careful consideration.

Frequency of Watering and Amount to be Applied.

One of the most important questions in irrigation practice is that of the frequency of water application and the amount of water to be applied at each watering. While in the past the farmer has been guided by intuition in determining when a further irrigation is necessary, investigations in recent years have provided us with a much more scientific outlook on these matters.

The problem is governed in the main by two considerations—(*a*) the water-holding capacity of the soil, and (*b*) the rate at which the moisture is removed from the soil by crop absorption and evaporation losses. The capacity of the soil to hold moisture has already been fully discussed, and it was stated that a clayey soil will retain more moisture in an acre-foot than will a similar depth of sandy loam. The latter soil will therefore demand more frequent waterings than the heavier textured soil. The rate of water absorption by the crop depends on both the stage of development of the crop and the season of the year. A young stool of cane, with its restricted root system and incomplete leaf development does not utilize moisture as freely as one which has attained its peak of leafy growth, supported by a root system which thoroughly permeates the soil. Moreover, the air temperature has a dominating influence on the rate of crop growth, and it has been shown that the growth rate may be forecast with accuracy on the basis of the mean atmospheric temperature alone, provided soil moisture and plantfood supply are adequate. The humidity of the atmosphere will, naturally, modify the rate of evaporation from the cane leaves and from the surface of the moist soil. In cases of extremely high temperatures and low humidity, the evaporation loss from the cane leaves may be so great as to cause the cane crop considerable distress, and despite favourable soil moisture, the growth rate is seriously retarded. With similar temperatures and a humid atmosphere, phenomenal growth rates are frequently recorded.

As a general rule, it may be assumed that a young crop requires rather infrequent light waterings, while a well-advanced crop will respond to heavy irrigations at ten-day intervals during the height of the growing season. Assuming that any water applied in excess of 5 inches at one watering is lost by deep percolation in the subsoil, the following might be regarded as a suitable watering schedule:—

Period.	Acre-inches Applied at a Watering.	Frequency of Irrigation.
May-August	2″–3″	3-week intervals
September-October-November ..	4″	2-week intervals
December-January-February	5″	10 days to 2-week intervals
March-April	4″	2-week intervals

Due allowance must, of course, be made for the incidence of favourable rains, though it will be found that irrigation should not be interrupted during the summer season until at least 2 inches of rain have been recorded. Watering should not be deferred until the crop exhibits obvious signs of distress; crop growth will have ceased several days before this condition is observed.

It is a well-established principle that at the time of planting the cane favourable soil moisture conditions should be aimed at. Irrigation should then be deferred until the crop shows definite symptoms of moisture deficiency. From the time irrigation is begun, the development of the crop should be continued uninterruptedly throughout its lifetime. Serious growth checks act detrimentally on crop yields, particularly when the crop is "making cane."

Position of Water Furrows.

The position occupied by the water furrows is a matter of considerable importance. It is the usual practice in Queensland to utilize the planting drill for the purpose, so long as this remains open. When it becomes filled due to cultivation operations, special water furrows are prepared between the cane rows, just prior to each watering. These are run at varying distances from the cane stools, but usually occupy the middle of the interspace. Doubtless this is not in the best interests of water economy; for to bring about a complete wetting of the soil mass occupied by the cane roots—and they spread rather in the form of an inverted cone below the cane sett—effective lateral seepage is relied upon. That this movement is small as compared with the rate of downward penetration is well recognised, and the desired result may be attained only by the application of excessive amounts of water. Doubtless two parallel small furrows in each interspace will prove more effective than one larger furrow.

This question is intimately connected with a problem which is often experienced under irrigated conditions—the production of profitable ratoon crops. Excessively deep furrowing inevitably leads to ridging of the cane row. This hilling-up process is not detrimental to plant cane, but it presents a serious obstacle to the early application of irrigation water to the stubble, to assure favourable growth conditions for the young ratoon crop. Further, the ratoon stool will become established on the land surface, instead of being set well down in the soil.

The farmer is therefore obliged to level down the ridges before the ratoons can be given anything like reasonable moisture treatment. This is effected by means of the "bumper" disc harrows, or better still, by means of the stubble shaver. The ratoons then require an early fertilizer application, and otherwise will demand as careful attention as does plant cane.

FIG. 64.—Illustrating the layout of irrigation drain and furrows in the Burdekin district.

Fertilization of the Crop.

It must be emphasised that the production of heavier cane crops, due to irrigation practice, must result in the more rapid depletion of soil plantfood supply than is the case with lighter yields. The application of heavy dressings of artificial manures is therefore of the greatest importance. The nature of the crop increases due to fertilizer treatment, when irrigation is practised, have been demonstrated clearly by the results of the farm fertility trials conducted by the Bureau. Failure to appreciate this fact will lead to disappointment in returns, and increased production costs. It is only during recent years that canegrowers of the Burdekin area have discovered that indifferent ratoon crops were obtained, even when liberally watered, when fertilizers—and notably sulphate of ammonia—were omitted from the programme.

IRRIGATION PROBLEMS.

Having satisfied himself that he has access to an adequate supply of good quality irrigation water, the farmer must decide upon the most suitable means of drawing on the supply, and delivering it to the land to be watered. Many alternative types of pumping and distribution equipment are available, and the grower must make his selection in conformity with the particular demands of his specific set of conditions.

He will generally find it best to seek the advice of an expert in this line, as he will thereby save himself much trouble and expense. It will not be possible in a brief chapter to deal comprehensively with all the aspects of the problem, but an attempt will be made to indicate certain of the major matters for consideration.

The Pumping Plant.

With few exceptions a modern-type centrifugal pump is found to be most satisfactory for raising irrigation water, under Queensland conditions, whether the supply be drawn from open water or from subterranean sand and gravel beds. In the choice of a suitable pump two major considerations command attention—

(1) Capacity, and

(2) Efficiency.

As an approximate guide to capacity, the farmer may accept the rule that by squaring the pump size in inches the number of thousands of gallons which the pump will deliver hourly is obtained. Thus, an efficient 8-inch pump, drawing water from an underground supply, will deliver 8 × 8 or 64,000 gallons of water per hour. Naturally this figure will vary between fairly wide limits, depending on several other factors, but it is a fairly good guide. Even a well-designed pump will attain a high degree of efficiency only when operated at a definite speed. The best speed for a given pump also varies with the "head" under which it is operated. Thus a pump drawing water from water beds 20 feet below the land surface must be operated at a different speed from that which would be necessary were the water being pumped from a depth of 40 feet. The advice of a qualified expert will assure the grower of reliable guidance in this connection.

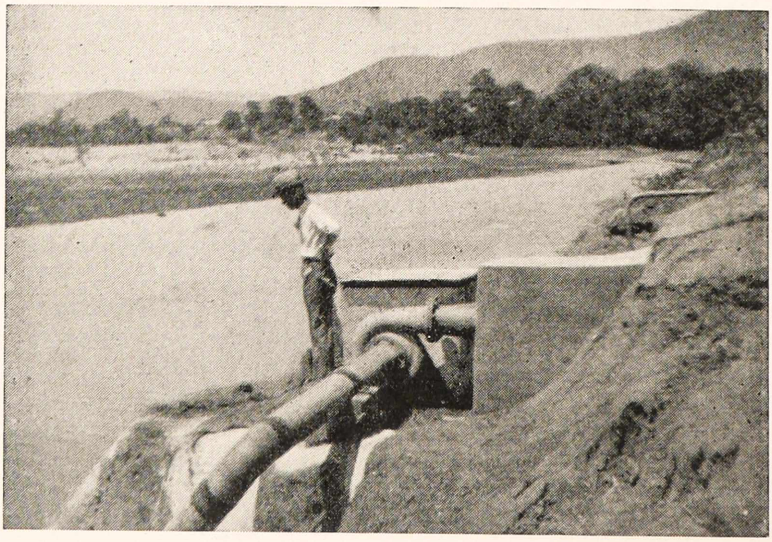


Fig. 65.—Irrigation pump operating on open water, Mulgrave River.

Engine.

The selection of a suitable power unit offers considerable scope. Four types are commonly employed—(*a*) steam, (*b*) suction gas, (*c*) internal combustion oil engine, or (*d*) electric motor. The older units were

almost all steam operated; then came the era of the suction gas engine, where an abundance of suitable firewood was available. More recently petrol and kerosene internal combustion engines were introduced, while the latest types are almost exclusively so-called "diesel" engines, which operate on crude oil. The last-named type has practically superseded all others. Occasionally, electrical power is employed, either from general service mains or from a central installation employing, say, crude oil or coal to generate electricity, which may be used to operate at will any or all of a number of pumps suitably located over the area to be watered.

It is reasonable to dismiss consideration of steam units in laying down a modern plant. Suction gas may warrant attention in particularly favourable circumstances, but, like steam, it demands the continuous attendance of an operator, which adds substantially to pumping costs.

The internal combustion oil engine—and notably the crude oil type—does not suffer from this handicap. While it must not be assumed that an engine of this class may be allowed to run unattended, it is true that intermittent supervision only is demanded, and the operator may devote attention to other duties as well. At the present cost of crude oil, and with the high efficiency of this type of engine, a maximum fuel cost of $\frac{1}{3}$d. per horse power per hour may be assumed.

The power of the engine required must also be considered carefully. While it is obviously unwise to attempt to overload the engine, it is not good business to over-capitalise the plant by installing an unduly high-powered unit. Expert advice is most helpful in arriving at a satisfactory decision; however, the following formula will provide the farmer with a fair estimate of power of a suitable engine, making due allowance for transmission and friction losses and overload margin:—

$$\text{H.P. required} = \frac{\text{Total head (suction, delivery and friction), in feet} \times \text{gallons of water per hour.}}{100{,}000}$$

That is, multiply the vertical distance in feet, from the water-level to the highest point of the delivery pipe, plus an allowance for friction losses, by the estimated volume of water the pump will deliver hourly, and divided by 100,000.

Pump.

Wherever practicable, it is desirable to install a horizontal centrifugal pump, operated by belt drive from the engine. As was indicated earlier, the pump must not be more than 25 feet above the level of the water, or it will not draw its supply. For preference, the pump should be placed as close as possible to the water bed. Where the water-bearing drift is, say, 30 feet below the land surface, a pit or well may be scooped or dug to a suitable depth, and the pump installed therein. The engine may then be placed at normal land level.

For deep supplies, the vertical spindle centrifugal pump becomes necessary. As the excessively long shafting required for this purpose demands adequate bearings, to assure true running, the heavy channel iron supporting frame for such a layout adds considerably to the installation cost. However, it is essential for efficient working with deep supplies of underground water.

A so-called "one-stage" centrifugal pump is satisfactory provided the total pumping head does not exceed, say, 100 feet. With greater

heads, the efficiency of the pump falls off at such a rapid rate that a two- or three-stage unit should be employed. Naturally, this will increase the installation cost to some extent, but it makes for reduced costs of operation.

To provide some indication of the manner in which the pumping costs per million gallons of water will vary with variation in the pumping head, the following examples are given. In each case a pump supplying 50,000 gallons of water is stipulated:—

Overall Head.	Nature of Pump.	Pump Speed.	Engine Power Required.
Feet.		Revolutions per Minute.	Horse Power.
25	Single stage–low head	1,230	11·5 net
50	Single stage–low head	1,480	19·0 net.
100	Single stage–high head	1,550	38·0 net.
200	Two stage–high head	1,550	76·0 net.

In making these calculations, allowance has *not* been made for the power transmission loss, which is often very considerable with an inefficient belt drive. Direct coupling of the pump to engine eliminates this loss, but is seldom practicable.

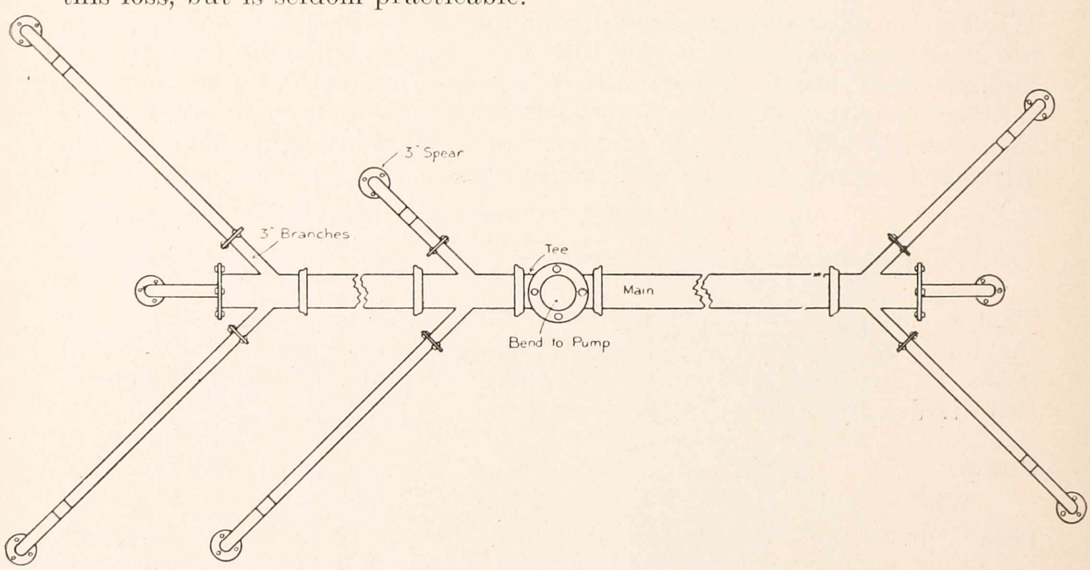


FIG. 66.—Illustrating the manner in which the spears are distributed to give an adequate water supply.

Where water is drawn from an open supply, it is only necessary to provide that the suction opening has access to an adequate depth of sand-free water, and to assure that it is not drawing air. Where an underground drift is tapped, care must be taken to ensure complete separation of all sand or gravel from the water entering the pump. The selection of suitable parts for the spear system is therefore of importance. It is found that, where the drift is of medium or fine sand, the rate of passage of water to the spear is relatively slow, and it is then desirable to connect a number of 3-inch spears to a common suction pump. With coarse sand or gravelly drift, fewer large-sized spears (6 inches) are a distinct advantage; they are simpler to install and also

less costly and troublesome to maintain. The accompanying illustration indicates the manner in which the spear system is spread out, to assure that a volume of drift is tapped, adequate for the full water requirements of the pump. Though there is nothing particularly difficult in installing a spear system, there are certain well recognised principles which must be observed for successful operation, and the grower would be well advised to seek expert guidance in this regard.

Wells are sometimes employed to provide the source of supply to the pump. In general, these do not have a high capacity unless combined with a spear system radiating outwards from the bottom of the well. However, it is frequently possible to obtain at least a 4-inch pump supply from open water in this way; such a unit is working successfully at the Mackay Sugar Experiment Station. The dry, upper portion of this well is lined with corrugated galvanised iron, in the form of a cylinder; when the water-bearing stratum was encountered, a brick lining was employed, and this was built up as the water-bearing sand was removed and the brick ring subsided. During the sinking of a well of this nature it is necessary to pump out the water at the same rate as that at which it enters; a centrifugal pump, the speed of which can be varied as required is desirable in this connection.

Water Distribution Problems.

When the water has been delivered at the land surface, the next problem is that of distribution. For preference, the water is delivered

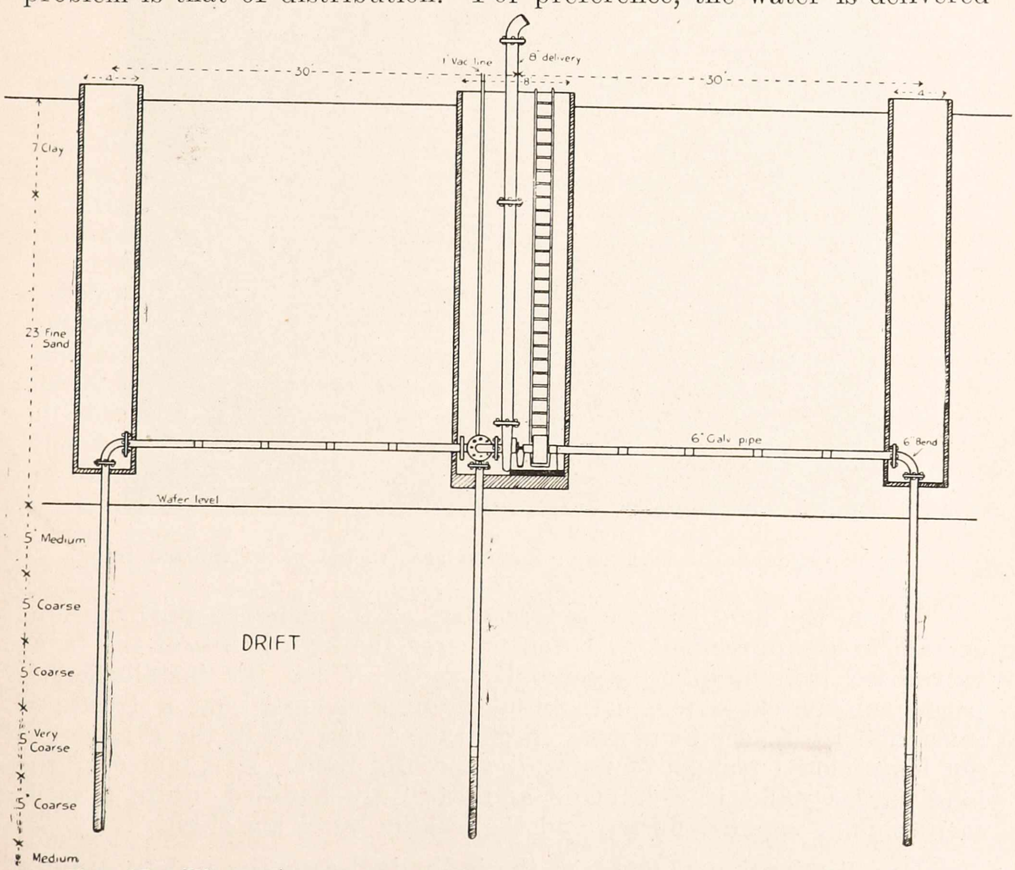


FIG. 67.—Illustrating concrete cylinder construction now commonly used in the Burdekin area. The cylinders are cast above ground level and lowered as the earth within is excavated.

at the highest point of the irrigated area. When this is not practicable, it must be carried sufficiently high by the pump delivery pipe to assure that it will gravitate over the farm. Several types of water channel are employed:—

(1) Earth drain,
(2) Lined drain,
(3) Open galvanised iron fluming, and
(4) Closed iron fluming.

Where the normal gradient of the land permits, the earth drain is simple and cheap to construct. In general the main earth drain follows the ridges of the area. This class of drain suffers from one serious drawback—the heavy water seepage losses incurred, particularly in porous soil. It has been shown that in some earth drains the loss of water may amount to 50 per cent. per mile of drain. In these circumstances it is usually worth the farmer's while to give consideration to concrete lining, at least of the main drains. The cost of the job will usually be amply repaid in the water saving effected.

FIG. 68.—Permanent half-round fluming constructed of galvanized iron.

Where the land surface is irregular, or the delivery pipe must be carried to an appreciable elevation to serve the high points of the farm, galvanised iron fluming is generally used. When the installation is permanent in character, half-round fluming mounted on a trestle is constructed. Where temporary in character, and where the gradient is not high, closed portable fluming is generally used. It is laid over the land surface, and if well made and carefully handled, quite a satisfactory joint may be effected and the leaking losses are slight.

For distribution of water at the individual cane lines, short lengths of 2-inch galvanised piping are most effective. These are set in the bank of the earth drain at such an elevation as to assure a regular flow of

water in all furrows. They may be transported readily from field to field, and their use eliminates the undesirable erosion of soil which is usually experienced where the water is allowed to flow from a notch in the side of the earth drain.

FIG. 69.—Showing the manner in which short lengths of 2-inch piping are used to deliver water to the irrigation furrow.

The layout of the irrigation furrows depends on the watering system employed. Many variations from standard practice are used, but the systems may be grouped into two main classes—(1) the contour and (2) the long-line. In the former the cane is planted on the contour, and the water ditches are placed at right-angles to these, i.e., in the direction of the slope of the land. This system was formerly the standard practice in Hawaii, but during recent years it has been replaced to a considerable extent by the long-line system, which is much more economical on labour and water. This is essentially the practice employed in Queensland. The water courses are placed around the contours of the land, and the cane furrows run at right angles. Whereas the length of the cane furrows for contour irrigation was of the order of 40-60 feet, the long-line system provides for furrows from 3 to 5 chains in length. The length of the furrow is governed by the type of soil and the slope of the land. These factors also govern the flow of water in the individual furrows. Thus, with a high slope of land (from 1 to 2 per cent. is the ideal grade), a much longer furrow is permissible than with flatter country. A relatively large stream of water flowing for a short period in a short furrow is best with a light-textured soil, while with clays and clay loams a small stream flowing for a long period is necessary to assure thorough saturation of the land.

Spray Irrigation.

Spray irrigation has been employed successfully with many crops, notably vegetables, small fruits, and lucerne. With sugar-cane it has received only scant attention, although quite an extensive system was laid out on one Hawaiian plantation some years ago. The chief drawbacks to the wider employment of the method at that time were—(1) the cost of the installation, and (2) the faulty distribution of water due to inherent imperfections in sprinkler design, and interference by wind.

More recently a new type of sprinkler has been devised, which possesses a large coverage, when operated at high pressure. The latest models have the following characteristics:—

Diameter of nozzle—$\frac{3}{8}$ inch.

Discharge—29 gallons per minute.

Nozzle pressure—45 lb.

Sprinklers per acre—3.

The greatly increased coverage over older types allows of a big reduction in the amount of piping required, while the pipes may be laid on the land surface without interfering seriously with cultivation operations.

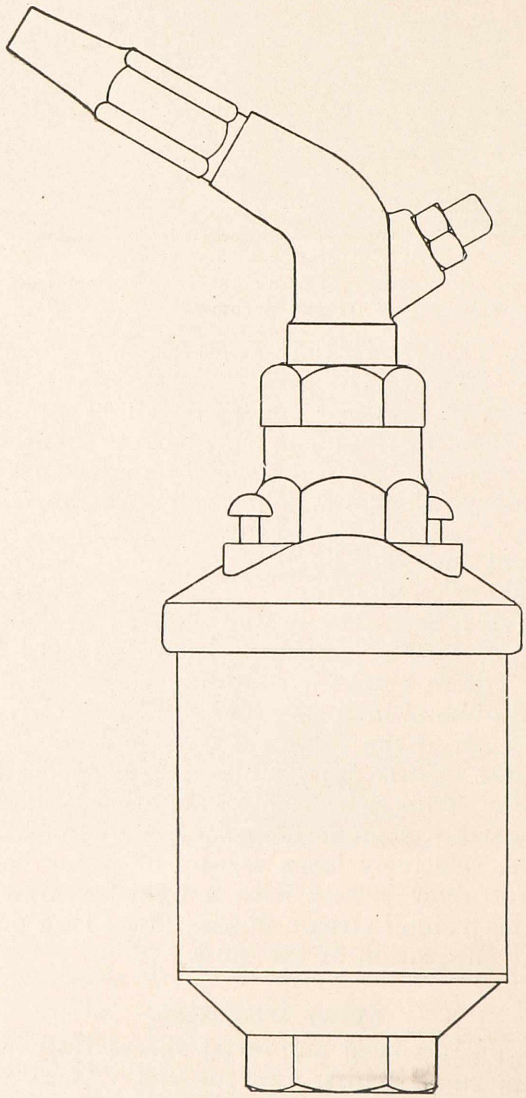


FIG. 70.—Illustrating the essentials of the high-pressure irrigation sprinkler.

The accompanying illustration (Fig. 70) shows the essentials of the sprinkler. The water enters at the lower end, from the standpipe, and as it passes upward operates a turbine which drives the nozzles,

through a system of enclosed reduction gears. This ensures a positive drive at a very low speed, with little chance of failure. Two jets are fitted—the larger which irrigates a wide ring, while the smaller provides a fan-like spray which takes care of the inner circle. The total coverage is a circle some 150 feet in diameter, when the sprinkler is set at a height of 30 feet. For cane irrigation, a standpipe of 18 feet would be more suitable, and the coverage would be slightly reduced.

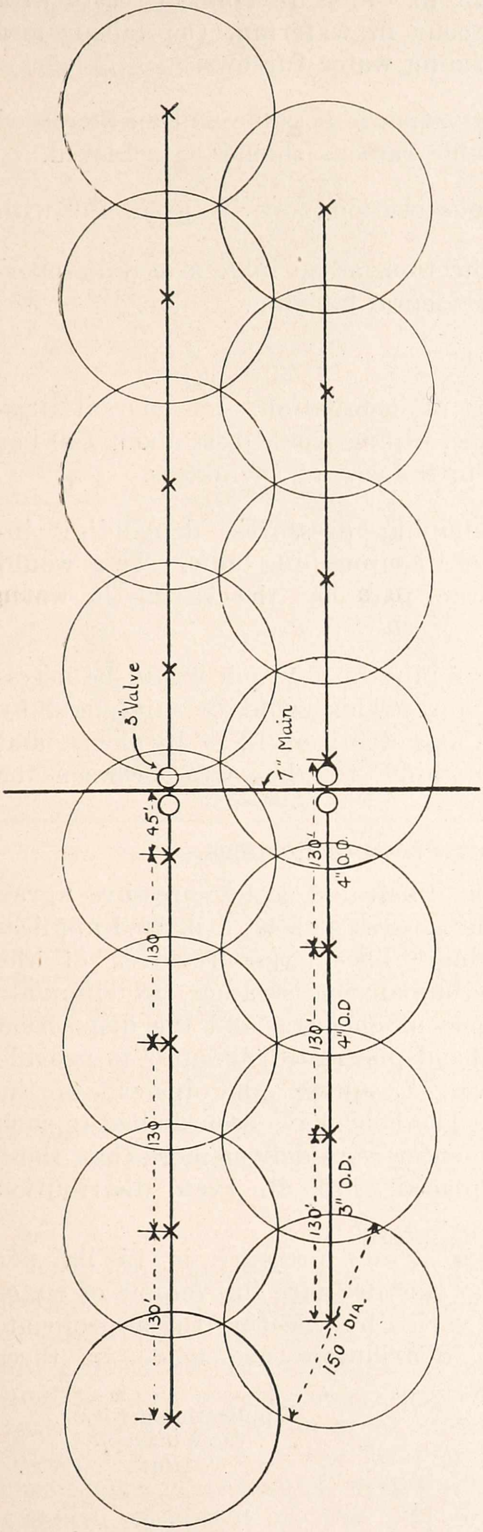


FIG. 71.—Illustrating a typical lay-out for high-pressure sprinklers.

Fig. 71 provides the plan of a typical installation, while the standpipe employed at the positions shown by crosses is illustrated in Fig. 72. The pressure required to operate the system is usually supplied by a two-stage centrifugal pump. The sprinklers described above are capable of applying $\frac{1}{4}$ inch of water per hour, and a typical layout, to be operated day and night, would require a 40 h.p. engine, driving a 5-inch pump, and allow of one watering per two weeks over an area of 140 acres.

The following are the main advantages and disadvantages of the sprinkler method of irrigation:—

Advantages.

(1) Economy in water utilization due to evenness of distribution of even light applications.

(2) Complete elimination of seepage losses from water course.

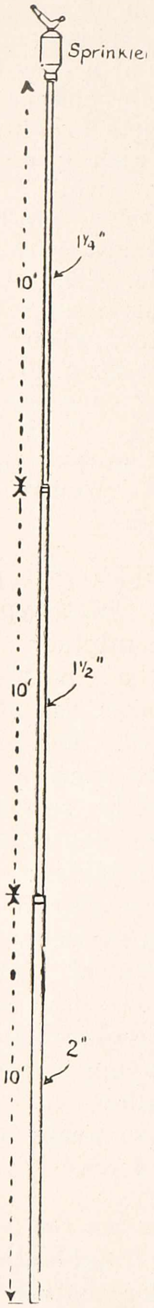


Fig. 72.—Illustrating standpipe for high pressure sprinkler.

(3) Reduction in water distribution costs with respect to (*a*) labour in watering, (*b*) labour and implements in forming water furrows.

(4) Flat cultivation is possible and an increased number of profitable ratoons should be achieved.

(5) Trash conservation may be practised with ease.

(6) Fire protection, as sprinklers may be operated to control accidental burning.

Disadvantages.

(1) High cost of installation. On current Brisbane prices the steel piping would cost about £40 per acre, in addition to the cost of sprinklers.

(2) High pumping pressures, demanding increase in power of the pumping unit. This would be off-set in a large part by the saving in water consumption.

(3) Moving of pipe lines which would be necessary when ploughing. This could be minimised by burying the main at a depth of 12 to 15 inches, and confining the ploughing to the area between the laterals.

Low Pressure Systems.

In Fig 73 is illustrated a low-pressure spray nozzle which might possess at least a limited application to canegrowing. The major features of the spray are the accompanying strainer, to eliminate most of the dangers of chokage, and the disposition of the holes on a hemispherical distributor to provide even watering over a square plot instead of the customary circle. The holes have been drilled in such a manner that the outer rows deliver more than those more centrally placed, and an even distribution results.

The operating nozzle pressure is 15 lb. per square inch, and at this pressure the volume of water delivered may be varied by selecting the appropriate distributor. The distributors are made in three grades, as follows:—

	Application per hour. (acre-inches)
8 rows of 8 holes	1·00
9 rows of 9 holes	1·26
10 rows of 10 holes	1·56

The coverage of each spray is a square of 35 feet side, when attached to a standpipe 1 foot high. This necessitates about thirty-six sprays to cover an area of one acre at a time.

With a crop such as cane, it would be necessary to place the spray on a standpipe of greater height than that suitable for, say, lucerne. The increased height would give substantially greater coverage for the spray, but also adds to the difficulty of transportation, if a portable

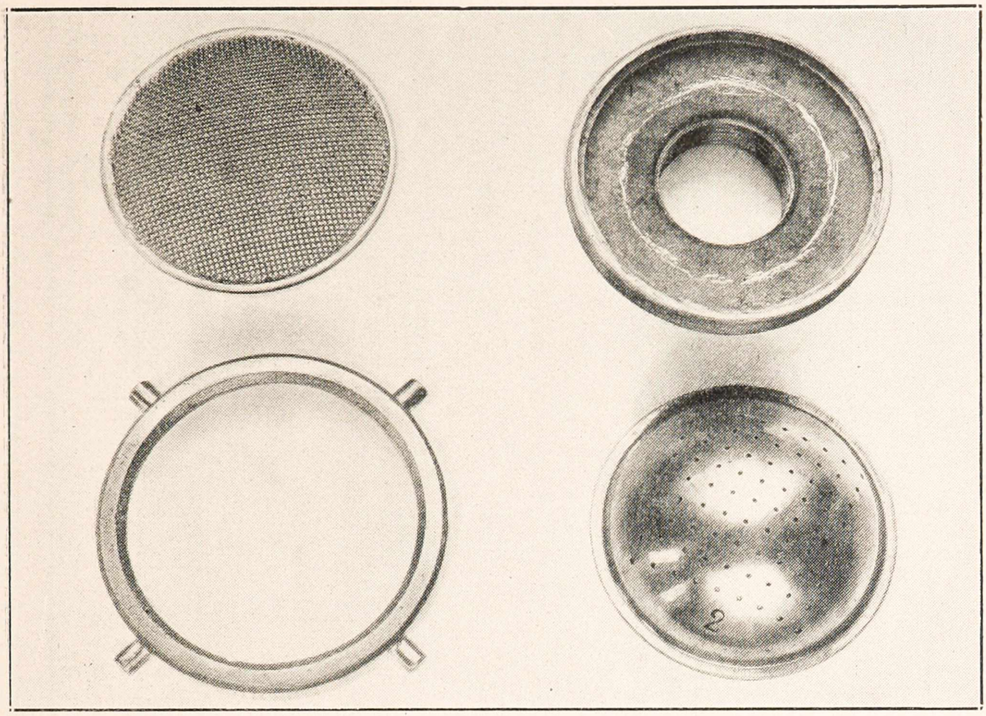


FIG. 73.—Showing the parts of the low-pressure spray described in text.

system is desired. In certain areas of Queensland where farmers are desirous of irrigating only during the (normally) dry spring and early summer, it would be possible to use a 6-feet standpipe, and this should not introduce any trouble during transportation.

The adaptation of the height of standpipe to stage of development of the crop could also be considered. It would be neither very costly nor troublesome to employ, say, 3-feet standpipes for young canes, and 6-feet pipes when the height of the cane demands it.

Suitable Layout.

To illustrate how such a spray system could be employed as a portable unit, a layout will be described in which a particular enquiry is dealt with. The grower in question has an area of sandy loam soil, approximately 20 chains in width, and divided into two almost equal parts by a permanent creek which runs through the length of the farm. By damming the creek, it would be possible to bring the water within, say, 8 feet of the level of the fields, which are virtually flat. A schematic layout which would involve the use of a tractor, with pump attached, is shown in Fig. 75, for which the following description applies:—

By means of a flexible hose, the water is drawn from the creek, through a footvalve and strainer, and forced by the centrifugal pump

through, say, three lines of sprays, set at intervals of 35 feet, for use with the unit already described. The field is 10 chains in length, and each spray line would therefore require nineteen sprinklers. Each

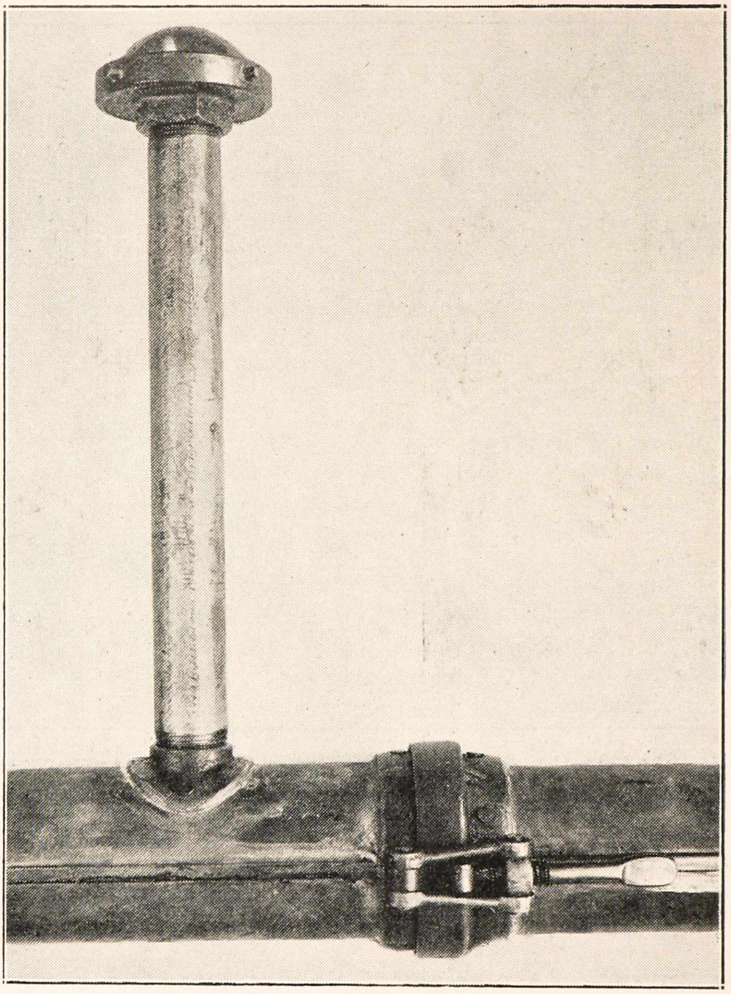


FIG. 74.—Illustrating the portable fluming, short standpipe, and low-pressure spray.

sprinkler (say, 64-hole type) delivers about 10 gallons of water per minute, so that fifty-seven sprays, in three lines, will distribute approximately 35,000 gallons of water per hour. This quantity would be delivered by a 5-inch pump. The headland main fluming could be 5 or 6 inches in diameter, while for the three laterals, a 4-inch round fluming would suffice.

The total head against which the pump would operate, with the above layout, would be approximately 70 feet, and the power required, 20 B.H.P. By employing 5-inch fluming for one-third the length of laterals, friction losses would be minimised, and the power required reduced by about 15 per cent. Such a layout (Fig. 75) would apply 3 acre-inches to 1·6 acres in three hours, when the system would be uncoupled and transferred 105 feet across the field. By using clip-jointed fluming (*see* Figs. 76 and 77), fitted with compression rubber

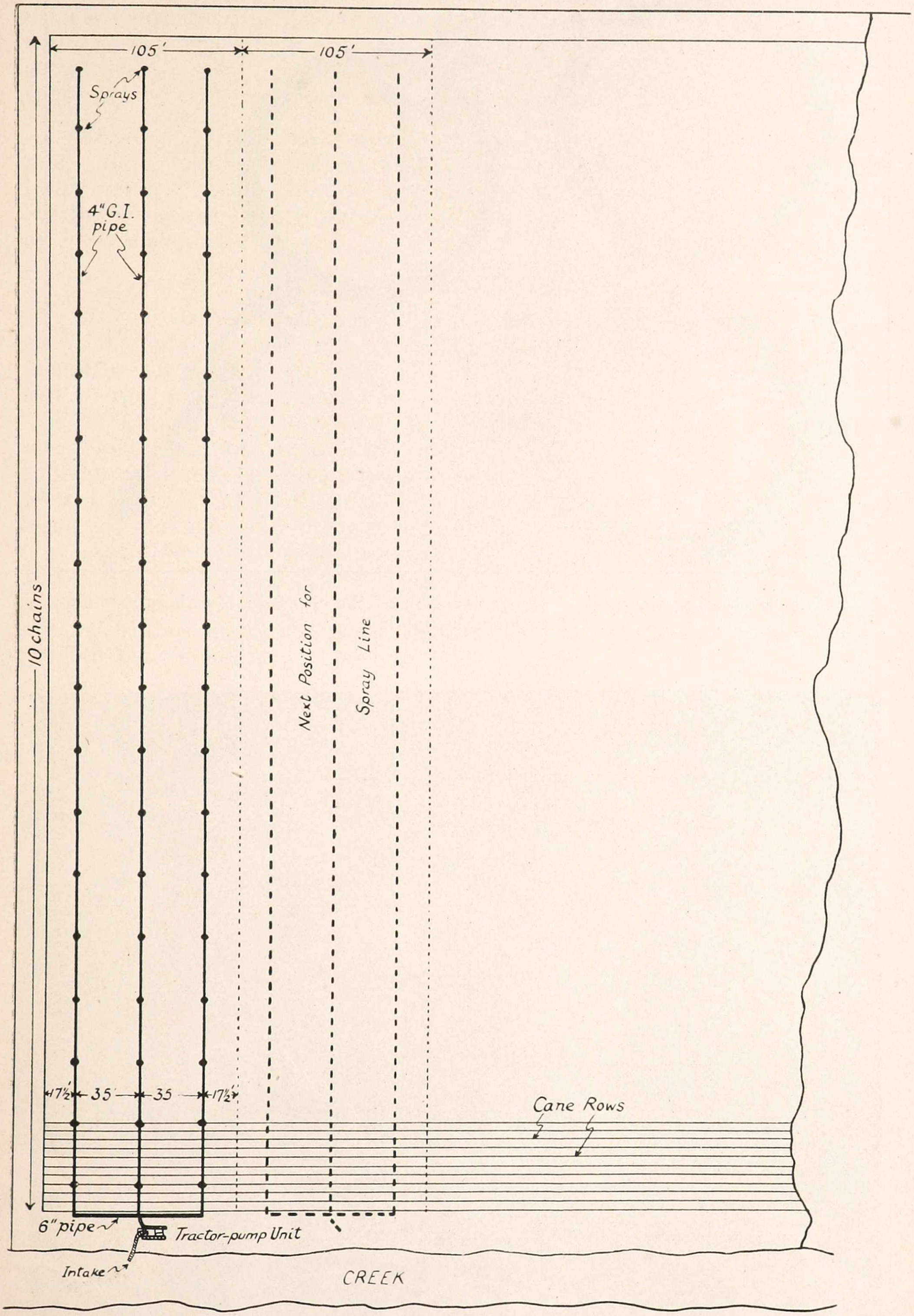


Fig. 75.—Showing a lay-out for spray irrigation, using portable fluming and low-pressure sprays.

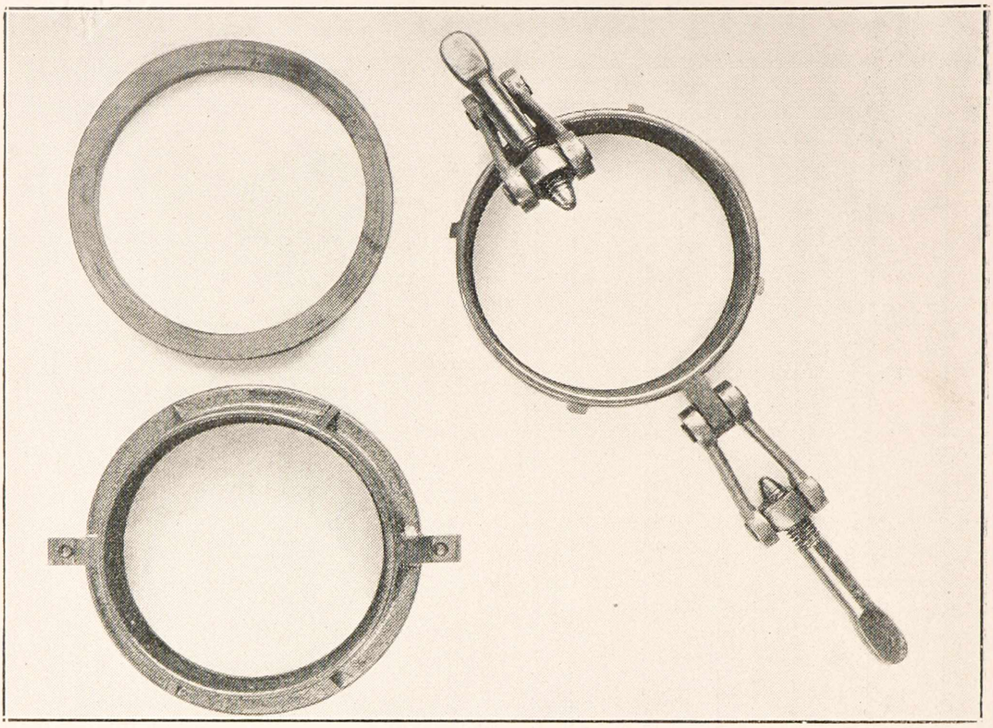


Fig. 76.—Illustrating the method of construction of the clip joint (with rubber ring) for portable fluming.

Fig. 77.—Another type of effective fluming joint used in Hawaii.

rings, this would present no difficulty with the lateral fluming. The tractor could be employed, if desired, to transport the four 17 feet 6 inches lengths of larger main, as well as the flexible hose coupling and intake pipe, when moving to its new position. Assuming that three strips (or 4·7 acres) can be sprayed in a 12-hour day, the system could take care of 47 acres where fortnightly waterings are desired.

The cost of the complete distribution unit (but *excluding* tractor and pump) would be about £200. Care should be taken to obtain heavy gauge fluming (say, 22 gauge) and, before use, protect it with a coating of tar or similar preparation if it is to be employed with water of a corrosive nature.

Water Corrective Treatment.

It has already been stated that certain natural waters contain such amounts of salt and carbonate of soda as may react detrimentally on both crop and soil. The chief danger from excess salt is the accumulation of the material in the soil, so as to act as a plant poison and kill the crop. However, continued application of salt waters will also injure the soil. The exact safety limit for this substance cannot be stated absolutely as it depends on a number of factors. The chief of these are the class of soil and subsoil (whether sandy or clayey), and the manner in which the water is applied. As a general guide, it may be assumed that a water containing more than 100 grains of salt per gallon should be used only with caution. Care must be taken to assure free subsoil drainage, and the water should be applied rather freely to wash out any salt accumulation which may tend to take place.

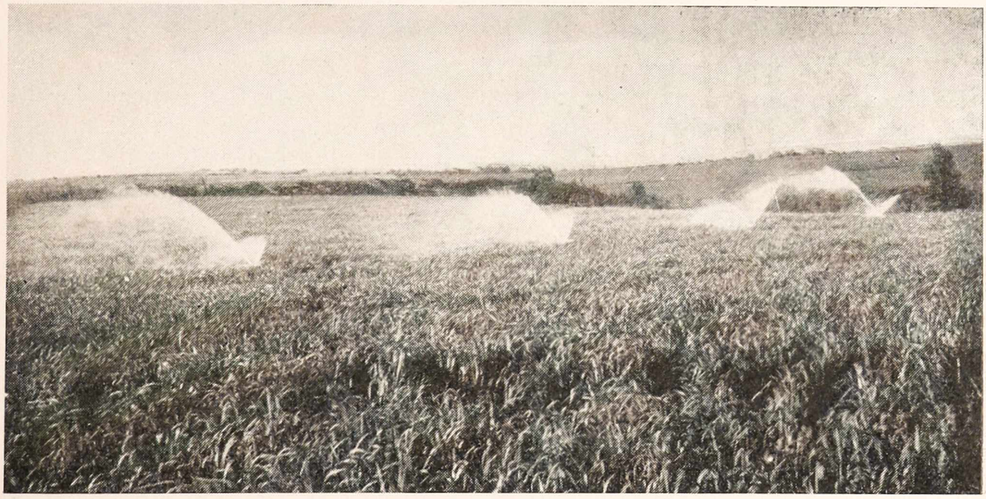


FIG. 78.— Showing the operation of wide-coverage sprays used with portable fluming in Hawaii.

The presence of sodium carbonate (free alkali) in a water, to the extent of even 10 grains per gallon, must be regarded with suspicion. This compound is both poisonous to the crop and damaging to the land. The effect on the soil is to cause it to lose its granular structure, so that it becomes sticky and "runs together"; ultimately, it may become quite impossible to cultivate the land.

This condition may be avoided or corrected by the use of substances which will "kill" or neutralize the carbonate. Such are sulphur and gypsum, applied broadcast on the land and worked into the soil. The use of sulphate of ammonia as the only source of nitrogenous fertilizer will also serve to correct moderate amounts of free alkali.

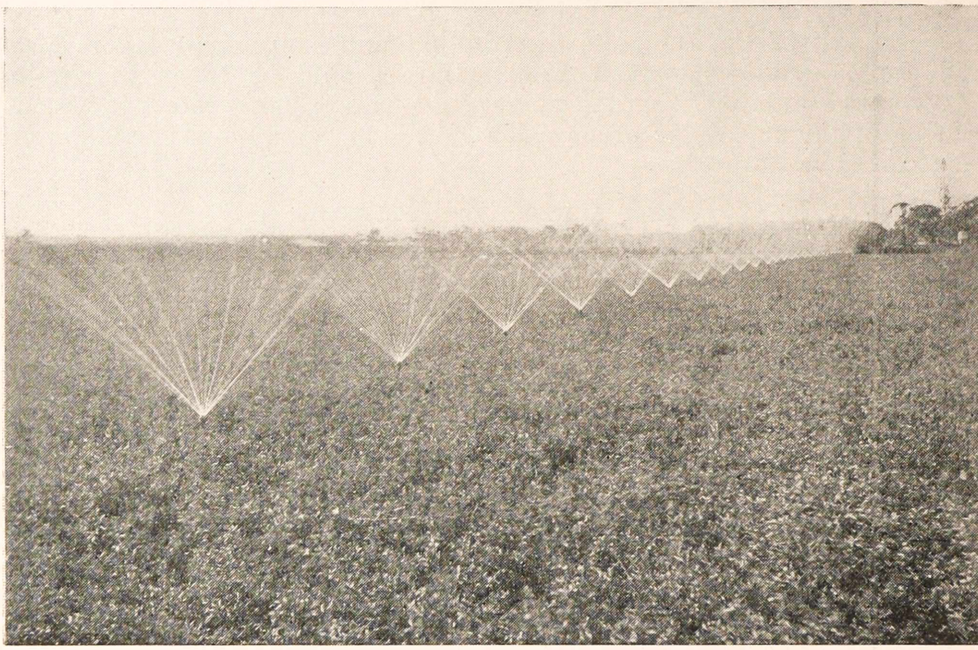


FIG. 79.—Illustrating one type of low-pressure spray which is successful with crops such as lucerne.

Any grower desiring advice in this regard should communicate with the Bureau of Sugar Experiment Stations. Above all, the grower should exhaust every possibility of locating a more satisfactory water supply before resorting to the use of highly saline or alkaline waters.

LAND DRAINAGE.

The question of land drainage is usually discussed in conjunction with irrigation for two main reasons—

(1) It is called for under conditions which are entirely the reverse of those which demand irrigation—that is, in soils with *excess* water, and

(2) Adequate drainage of the land is essential for successful irrigation, to avoid the accumulation in the soil of harmful concentrations of salts introduced by the irrigation water.

Although cane is a water-loving plant, it nevertheless demands a well-drained soil, in order that its roots may have access to a goodly supply of oxygen from the soil atmosphere. It possesses this characteristic in common with all "dry land" plants. When a well-tilled soil is thoroughly wetted, its entire pore space is momentarily filled with water; but under free drainage conditions, a large proportion of the water flows to lower levels, and leaves the soil in a moist condition which contains approximately 50 per cent. by volume of solid particles, 25 per

cent. of water, and 25 per cent. by volume of air. These are ideal conditions for the growth of crop roots, which must "breathe" to effect their life processes, and they also favour the work of the helpful soil micro-organisms. Should the air be completely excluded, as is the case with a so-called "water-logged" soil, the soil mass consists of about 50 per cent. by volume of solid grains, and 50 per cent. of water. Under these conditions, the growth of crop roots is suspended, the helpful soil bacteria are unable to function, and those which destroy nitrates and produce poisonous soil compounds are able to thrive. The effects of water-logging of the land are rapidly revealed in a yellowing of the cane leaves, and a generally stunted and unthrifty appearance of the crop.

FIG. 80.—Illustrating a wet depression in a canefield, Mackay district.

The remedy for excessive soil moisture is obvious; such conditions must be created in the land as will lead to a rapid removal of the surplus water, and the restoration of the soil air which automatically takes its place as the excess water is drained out. The methods by which this is customarily effected may be grouped into two broad classes—(1) Surface drainage, and (2) sub-drainage methods.

Surface drainage is most commonly employed in those cane areas where water-logging is experienced. It consists in the provision of shallow drains running in the direction of the slope of the field, into which the excess surface water flows in times of heavy rainfall, and is then carried off at the lower end of the field. This is usually effected by planting the cane in "beds." These beds are prepared by ploughing in narrow lands, which follow the slope of the ground surface, and leaving the dead furrow open, to serve as a water course. Cross-ploughing is, of course, not permissable in these circumstances. The width of the bed varies with the particular conditions. For flat country and clay soils, 2-row beds are found most useful, while under better conditions of drainage 10- or 15-row beds will suffice. Bedding serves to provide the necessary drainage water furrow, the soil from which will add to the depth of soil on the bed. It is essentially a method of converting a given area of (usually) mediocre land into a reduced acreage of appreciably increased fertility and productivity.

The provision of a satisfactory system of surface drains presents no great difficulties, provided the work is carried out with due care and forethought. Obviously, the surplus water must be carried to a

lower outlet than the lowest level of the field—that is, to a natural watercourse or swamp. Sometimes this is difficult to achieve, but such expedients as the scooping of headlands to the depth of the subsoil will provide soil for the building up of the beds, while supplying

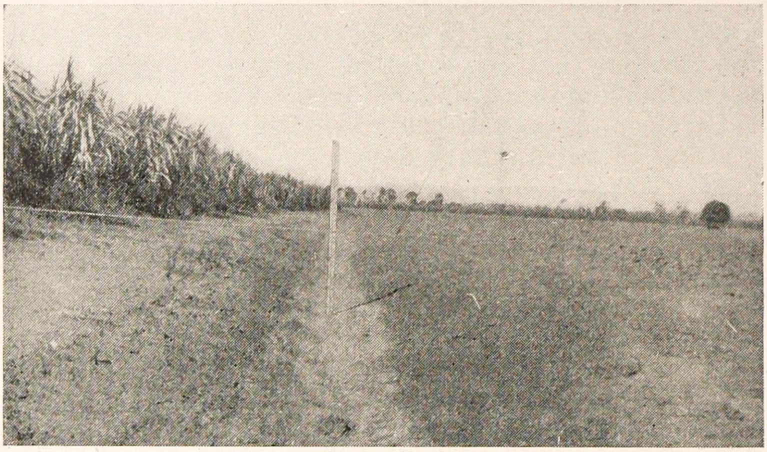


FIG. 81.—Showing the manner in which adequate surface drainage will enable the productivity of flat, low lands to be improved.

a suitable main watercourse; and the scooping away of ridges will provide material for filling the adjacent hollows. A simple horse scoop or automatic tractor unit is very helpful in this work, while a land leveller or grader (Fig. 82) simplifies the problem of providing a uniform surface for the beds, and eliminating any suggestion of localised basin-shaped hollows which may easily arise when headland scooping is carried out.

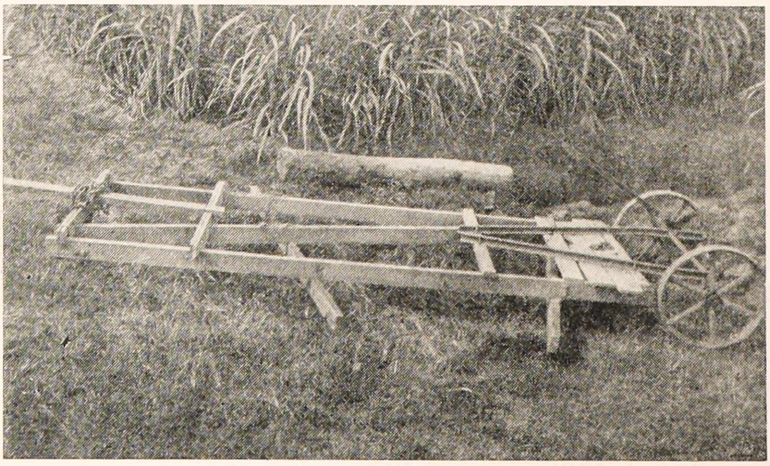


FIG. 82.—A simply-constructed grader which assists greatly in smoothing the land surface after scooping.

Though surface draining is the customary practice in the wet lands of the Queensland cane areas, it possesses one important limitation; it enables excess water to be removed only to the depth of the water-furrow. In many instances this may be a mere 10 or 12 inches, while the subsoil remains saturated, and the cane crop must depend

on the development of its surface root systems, so long as the subsoil remains in this condition. To overcome the trouble, an adequate system of subdrainage is imperative. That this method is not employed more commonly is explained by the costly nature of the work; but the lasting benefits which it would confer in the direction of improved crop yields suggest that it may be worthy of more than passing consideration by the canegrower. It is pleasing to note that a number of cane farmers are now installing earthenware drains.

The most satisfactory method of subdrainage consists in the excavation of trenches at intervals across the field, in which are set special agricultural tile pipes. These are placed end to end without any cementing material, and the small openings thus left at the junctions serve to admit the surplus water which flows from the water-saturated land. The trench is finally refilled with soil. Given an adequate fall (2 inches per chain will suffice), the water is then conducted to a lower portion of the block, where it is discharged into a larger main tile drain, and eventually led to a swamp or natural watercourse.

The desirable interval between parallel tile drains varies with the nature of the soil and the amount of water to be removed therefrom. In very heavy clay soils, one line of tile is necessary every 10 yards, but normally they are set 1-2 chains apart. The customary depth of the line of tile is 2 to 3 feet, but this will be governed very largely by the elevation of the discharge end of the field.

An expedient which is often adopted by canegrowers, to eliminate the cost of tiles, is the construction of covered drains filled with rocks or saplings, or drains lined with planks (box-drains). These are effective so long as they remain unclogged; but they are often short-lived. A more attractive method is that employing the mole-drainer. This interesting implement was designed for the purpose of pressing through the subsoil a bore, which remains intact after the torpedo shaped piercer of the implement has passed, and which serves as a conduit for the surplus soil water. The precautions to be observed in the construction of mole drains are similar to those demanded with tile-drainage. They must be run in the direction of slope of the field, and an open drain must be provided for their discharge. By reason of the cheapness of the operation, they may be constructed at intervals of from 10-15 feet across the field, and it is possible to provide 2-inch mole drains, 15 inches below the surface, by the aid of a light tractor, operating under ideal conditions.

The main drawback of the mole drainer is that it works successfully only where the character of the subsoil is entirely suitable. It is found that a greasy or ''puggy'' clay subsoil is ideal, as it retains the form of the mole after it has passed: where the subsoil is liable to crumble when dry, cracks develop, and the structure collapses. Unfortunately this device can be operated successfully on only a fraction of our poorly-drained canelands, but wherever conditions are suitable, its use is recommended.

Very often the cause of poor drainage is the existence of a handpan layer—either natural or artificial—in the subsoil. Under these conditions it is found that the use of the grubber or subsoiler will effect a substantial improvement in soil drainage.

It must always be remembered that "prevention is better than cure." And when the flooding of the land is the direct result of the incursion of surplus water from adjacent non-cultivated land, every effort must be made to head-off this supply before dealing with the problem of the land under cultivation. This is frequently the case where the block is at the foot of a hill, and the provision of a contour open drain just above the block is generally effective.

Finally, it should be stressed that clayey soils are not the only ones liable to waterlogging. There exist in Queensland areas of sandy loam which are underlain by stiff clays, and these are some of our least well-drained areas.

Chapter VIII.—SOIL ACIDITY AND LIMING.

Early records show that the value of lime as a soil improver was known to agriculturists over 800 years ago, and its use has persisted as a standard practice through the intervening centuries. It is only quite recently, however, that its true functions have been clearly understood. Lime is, strictly speaking, an essential plantfood, and in its complete absence the soil is quite sterile. The relative needs of various plant species for this nutrient vary widely, however. Lucerne and many other legumes appear to thrive only in soils abundantly provided with this plantfood. Sugar-cane, on the other hand, is not a lime-loving plant, and the employment of lime on the cane soils of the State must be traced rather to its virtues in other important respects.

These may be listed briefly as follow:—

(1) Neutralization of harmful soil acids;

(2) Provision of an environment more favourable to the helpful soil bacteria;

(3) Rendering plantfoods in the soil more readily available to the crop;

(4) Enabling fertilizers to exert their full influence on cane yields;

(5) By continued use on clays and clay loams, tending to improve their physical state and favouring the production and maintenance of good tilth.

Under our conditions, lime is employed primarily for its influence on soil acidity. In regions of high rainfall continued leaching results in the rapid removal of lime, and often induces an acid condition in the soil; in extreme cases the soil becomes so intensively acid that crop growth is completely suspended. Such lands actually exist in localised areas in North Queensland. It is the destruction of the poisonous acids by liming which promotes also increased activity among the soil microbes —those tiny inhabitants of the soil, which feed on the soil organic matter and yield valuable plantfoods and humus as the by-product of their life processes. Certain of these little workers also, which normally effect the necessary conversion of fertilizer to a form in which it is absorbed by the crop roots, are unable to function under intensively acid conditions. Further, results are on record which show that sulphate of ammonia may actually reduce crop yields on soils of this nature. Following an application of lime, the same soils gave pronounced results from the use of this valuable fertilizer.

A confusion of terms appears to have arisen out of the use of the words "sour" and "acid" to describe the condition of certain soils. The farmer frequently applies lime to heavy, wet, ill-drained lands which he describes as "sour." The use of this material frequently facilitates the drying out and "sweetening" of the soil, as the farmer expresses it. It should be clearly understood, however, that the "acid" soils so far discussed comprise many of our best-drained lands such as the alluvial loams of the Innisfail and Babinda areas. The function of the lime on these lands is essentially to neutralize the soil acids; and though the heavier soils of this type are markedly improved in tilth following the use of lime, this is rather incidental.

KINDS OF LIME.

When a grower proposes purchasing lime, he is frequently perplexed by the range and variety of materials from which he may make his choice. A brief description of the important forms of lime may clarify the position, and indicate the several factors to be considered.

Lime occurs naturally in the form of deposits which vary considerably in their physical condition. All have, however, the same chemical composition—*carbonate of lime,* or "agricultural" lime as it is popularly known in its marketed form. Marble, limestone, coral lime, and earth lime (or marl) all contain this compound as their active ingredient, though they may show a wide range of incidental impurities in the form of clay or earthy matter which reduce their monetary value. Coral and marble are usually very pure forms of lime, while earth lime frequently contains as little as 40 per cent. of this constituent. On the other hand, certain earth lime deposits which are exploited in Queensland show as high as 95 per cent. of lime carbonate.

Another form of lime which is frequently employed is known as *burnt lime.* This form does not exist naturally, but as the name indicates it is manufactured from carbonate of lime by the process of burning. If we should burn 100 lb. of pure limestone or marble, we would obtain 56 lb. of burnt lime. The proportion which is lost (44 lb.) consists of carbonic acid gas or carbon dioxide, which passes into the atmosphere. Burning therefore results in a concentration of the active material, none of which is lost in the process. If a compact lump of burnt lime should be exposed to the air, it will be found that it slowly increases in size, and gradually crumbles to a very fine white powder. The action of the atmosphere in this respect is simply a reversion of the burning process, and the "air-slaking" as it is called results in the re-absorption of 44 lb. of atmospheric carbon dioxide by every 56 lb. of burnt lime, to give once again 100 lb. of carbonate of lime.

Now it is a well-known fact that the different forms of lime exhibit pronounced differences with respect to the speed with which they effect their beneficial influence on the soil. Burnt lime is consistently superior in this regard; and though the caustic action of the fresh material is often considered a serious objection by the person spreading it, this effect may be largely minimised by air-slaking prior to spreading. It may appear somewhat difficult for the farmer to understand why the carbonate of lime which is again produced by slaking is so definitely superior to other forms of carbonate of lime. The explanation lies in the fact that the speed of action depends entirely on the fineness of the product. Lime does not readily dissolve in the soil moisture, as do soluble mineral fertilizers, and the rate at which it reacts with the solid acid substances in the soil depends on the degree of intimacy with which the lime and soil particles can be brought together. If the grower expects quick results from liming, the necessity for having the lime finely powdered will be readily appreciated. Air-slaking of burnt lime actually effects this desired condition most effectively, but the practical difficulties associated with the mechanical disintegration of limestone generally result in a marketed product which, though apparently well pulverised, still contains particles which are exceedingly coarse when compared with the particles of air-slaked lime.

A series of tests was made in our laboratory to determine the relative value of different sources of lime, and to determine the relative speeds at which they worked in the soil. It was found that the only feature of importance was the fineness of the material. Thus the finest pulverized chalk had completed its work within a month of mixing with the soil, while pieces of crushed marble averaging 1/20 inch in diameter had acted to the extent of only 3 per cent. after six months. A sample of high-grade commercial crushed limestone showed 50 per cent. activity during the first month, after which time its action was progressively slower due to the fact that only the coarser and slower-acting particles remained.

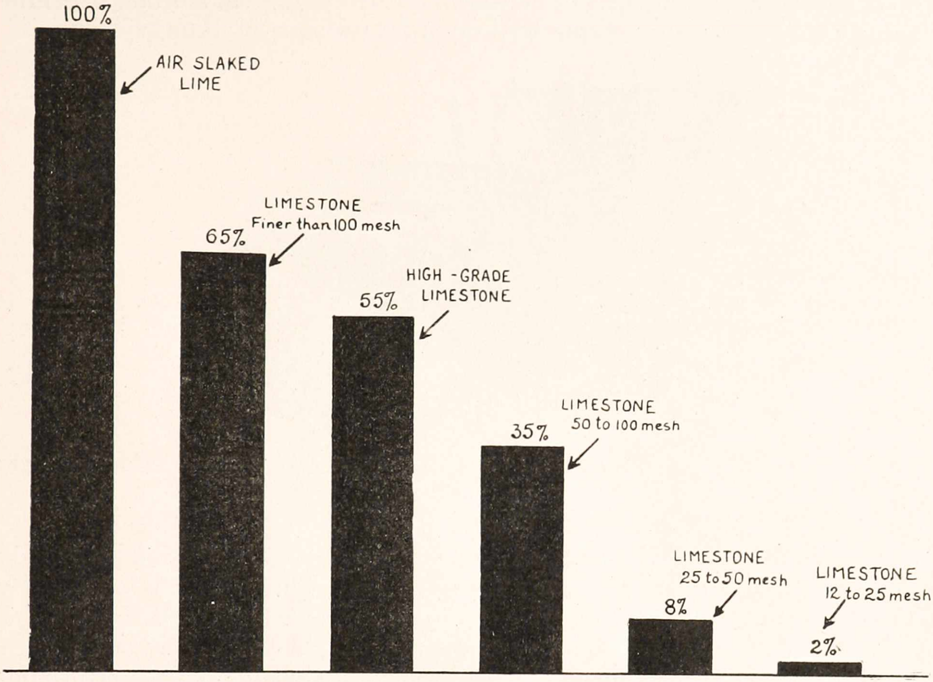


FIG. 83.—Illustrating the relative speed at which different samples of limestone reacted with soil acidity over a period of three months. It is evident that the finer the lime, the higher its value for speedy results.

It may be taken as a safe test that if the bulk of the lime passes through a sieve with 100 meshes to the inch, it will give rapid and satisfactory results when applied to the soil. In countries where lime occurs in abundance, and may be obtained for agricultural use with ease and economy, the fineness of grinding is a relatively unimportant matter, as slowness of reaction may be off-set by heavier applications per acre. But in a country such as Queensland, where the cheapest form of earth lime costs considerably more than £1 per ton at the nearest railway siding, the fineness test is a matter of considerable importance.

The farmer is often at a loss to determine whether it is more economical to purchase burnt lime or agricultural lime (crushed limestone or earth lime). Several points require consideration before a true conclusion may be reached. Firstly, 1 ton of *pure* burnt lime is equal in agricultural value to $1\frac{3}{4}$ tons of *pure* limestone. Secondly, the freight and transport charges will be proportionately less for burnt lime, for this same reason. Thirdly, a good quality burnt lime will give much quicker results than normal grades of crushed limestone. It should also

be remembered, however, that these remarks apply to *pure* burnt lime, which is scarcely realisable in practice, and unfortunately, the requisite care is not always taken to ensure complete burning of the limestone, so that large pieces of unburned stone are counted in as burnt lime. The caustic effects of burnt lime are also regarded by some growers as objectionable, though this quality may be destroyed quite readily by dumping the lime in small piles on the field, and allowing it to air-slake for two or three days before spreading. On the other hand, agricultural lime lends itself to mechanical spreading through a lime distributer; this assures both low spreading costs and even application. At the present time slaked burnt lime may be purchased. This fine material may be applied directly by the use of a distributer. These machines are now commonly loaned by lime firms with every purchase of lime.

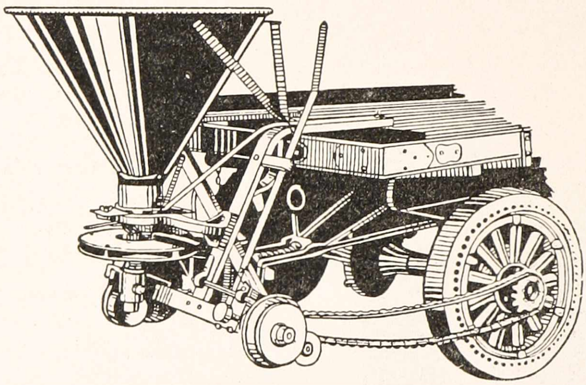


Fig. 84.—Illustrating one form of lime distributer attachable to a table-top lorry or truck.

In general, an initial application of burnt lime will ensure speedy neutralization of soil acidity, and quick results. Thereafter, good quality agricultural lime may be applied as required to maintain favourable conditions. On the acid alluvial soils, which give outstanding results from liming, an application of 1 or 2 tons of agricultural lime each time the land is replanted will be found worthwhile. The lime should be spread broadcast following the final ploughing, and harrowed or disced into the soil.

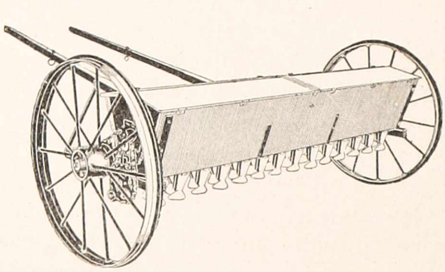


Fig. 85.—Showing the usual form of distributer employed in Queensland.

If the farmer is in doubt respecting the need for lime on his land, he should submit a sample of soil from the block in question to the nearest Sugar Experiment Station, with a request for advice in this respect; or the Bureau field officer will gladly take the sample and make the test immediately. It must be stressed that any advice given as the result of such tests is based exclusively on the presence or absence of harmful amounts of soil acidity. If the grower is of the opinion that

a lime application would "sweeten" a block of tight clayey land, we leave this entirely to his discretion, and his course will be independent of our advice on acidity.

An alternative to liming just prior to planting the cane, as recommended above, is to apply the material before broadcasting his green manure seed. Legumes benefit extensively from the presence of an abundance of lime in the soil, and the benefits from liming may therefore be made doubly valuable.

Finally, many growers desire to apply lime to ratoon crops, rather than delay the application until the block is in fallow. This is quite a satisfactory plan. The lime—either burnt or crushed limestone—may be broadcast on the trash from the previous crop before this is burnt off.

Chapter IX.—AGRICULTURAL VALUE OF MILL BY-PRODUCTS.

When discussing our crop it was indicated that sugar cane is a gross feeder, and extracts substantial amounts of plantfood from the soil. These are utilized in the process of crop growth, and when the cane is ready for harvest they are distributed throughout the trash, tops and stalk. If the farmer conserves his crop residues instead of burning them, all of the plantfood which they contain is eventually returned to the soil whence it came. But there is still a large proportion of nitrogen, phosphoric acid, potash and other nutrients which is carried off to the mill, and is permanently lost to the farm unless the grower takes steps to have them brought back.

When the cane is crushed it becomes separated into its major parts,

(*a*) the juice,

(*b*) the fibre or *bagasse*.

From the juice raw sugar is produced; this consists of almost pure carbohydrate, while most of the impurities of the juice are eliminated in the manufacturing process. It happens that these impurities contain the bulk of the plantfood and other valuable agricultural materials which are dissolved in the juice. They become concentrated in the muds or filter press cake, and the molasses, which are the by-products of manufacture. In so far as the bagasse is concerned, this material is burned to provide the power necessary to operate the mill, and in the process certain of the plantfood materials it contains are lost—notably nitrogen. The mineral plantfoods, however, are mainly concentrated in the furnace ash.

It is therefore evident that if it were possible to return to the cane lands all molasses, muds, and furnace ashes, the bulk of the plantfoods removed by the cane crop would be restored to replenish the fertility of the land. The only factors concerned in the utilization of muds and ashes are economic, and the advisability of the practice is governed by the cost of transportation and spreading. Molasses is often devoted to other uses, as in the manufacture of alcohol (power alcohol or potable spirit), or to supplement the fuel supply of those mills which are not able to obtain their requisite steam power from bagasse alone. The time appears to be approaching, however, when this by-product will be available for more extensive agricultural use. It is therefore of interest to discuss the agricultural value of these several products in some detail.

PLANTFOOD VALUE OF MILL BY-PRODUCTS.

If we should analyse the several products of the sugar-mill to determine the manner in which the three major plantfoods entering in the cane are disposed of we would find—

Plantfood—	In Raw Sugar.	In Bagasse.	In Molasses.	In Muds (or Press Cake).
	%	%	%	%
Nitrogen	3	56	31	10
Phosphoric Acid	2	39	24	35
Potash	2	23	74	1

Considering now the several by-products individually—

Molasses.—This by-product contains some 43 per cent. of the major plantfoods which entered the mill in the cane. The average composition of Queensland molasses is as follows:—

	Per cent.
Nitrogen	0·9
Phosphoric Acid	0·3
Potash	3·0

The materials are all present chiefly in a water-soluble condition, and would therefore become readily available for plant nutrition when applied to the land. On current fertilizer values, molasses would be worth about 27s. per ton *on the farm.* The true value to any particular farmer will be governed by the nature of the soil to which it is applied. It would be more valuable on a potash-deficient red volcanic loam than on an alluvial soil well supplied with potash. Of course, the cost of transportation and spreading of this bulky material must also be carefully considered in determining its economical utilization; but with the simple methods which are now commonly used for transferring the molasses, by employing a galvanised iron tank mounted on a motor truck, and its distribution directly on the cane fields, it must be agreed that the material has very distinct possibilities as a fertilizer, when the haulage distance does not exceed 2 or 3 miles. By reason of its composition, this by-product might be expected to produce best results on those soils highly deficient in potash—the plantfood present in greatest amounts. It was actually found that on the red volcanic soils of Bundaberg, each ton of molasses applied was responsible for a crop increase of 3 tons of cane over plant and ratoon crops. However, substantial and profitable increases were also recorded at Mackay and South Johnstone on two distinctive alluvial types not deficient in potash.

Experience shows that the most suitable dressings of molasses are from 5 to 10 tons per acre; the material may be applied either on fallow land or on ratoon fields, apparently equally successfully. We would recommend, for preference, that the by-product be broadcast on fallow land, allowed to rot thoroughly, then ploughed in and the land worked up for cane planting.

Another aspect of the benefits to be derived from the use of molasses as a soil improver lies not in its plantfood content, but in the organic matter which it contains. This consists largely of sugars, which are greedily seized upon by the micro-organisms of the soil; and if a chunk of soil saturated with molasses were examined a few weeks after the application, it would be found that it is completely permeated with greenish fibres of fungus tissue, which decompose in turn, and give a residue—small though it be—of humus-like material encasing the individual soil granules. The importance of this effect on the physical condition of the soil is very often profound, and many lands have been markedly improved in structure and tilling qualities by an application of molasses. Moreover, the influence is more lasting than that derived from a green manure crop, and may be detected after several years.

Molasses may also be employed to advantage to assist in the rotting of trash. If the molasses be spread over the trash just before it is ploughed under, the plantfood supplied by the by-product serves as a

source of essential foods to the tiny organism which bring about the trash decomposition, and speed up the process very much.

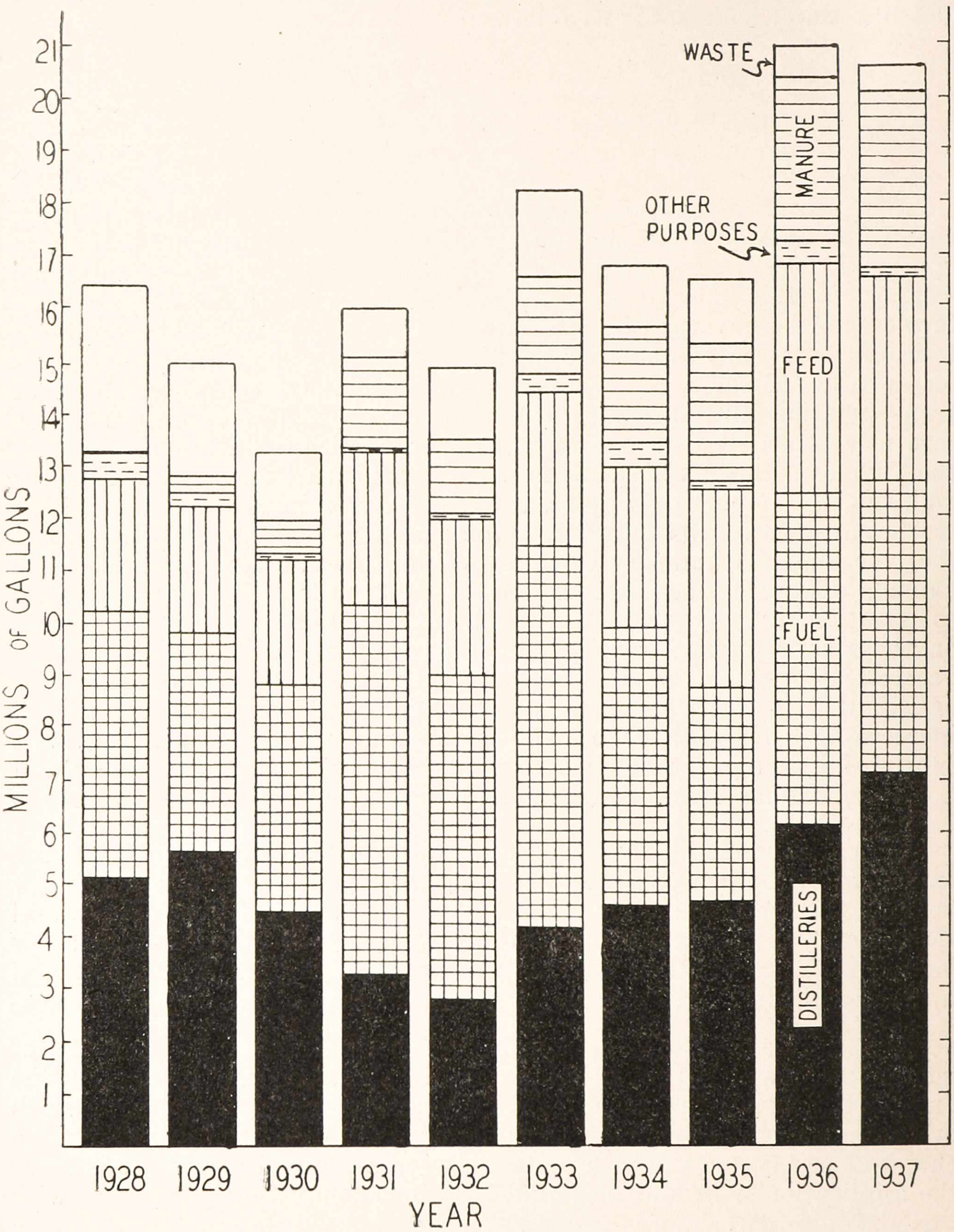


FIG. 86.—Graph, showing the manner in which Queensland molasses has been disposed of. Note the marked increase in quantities employed as stock-feed and manure.

An alternative method of utilizing molasses on the farm, and one which makes better use of the large quantities of valuable sugars which it contains, is that of feeding it to farm animals. Feeding experiments have demonstrated very definitely that farm horses will consume up to 8 lb. of molasses per day in this manner, and the farmer's feed bill will be correspondingly reduced by removing the need for those concentrated feeds which supply mainly starches, such as maize. On our Experiment

Stations we are employing roughage—either cane tops or grass—to provide bulk, molasses to supply the carbohydrate (or "energy" food), and peanut or cottonseed meal to make up the protein deficiency in the diet. It should be remembered that all plantfoods which enter the ration of farm working animals are entirely returned to the soil in their urine and solid excrement. Thus a twofold benefit is experienced, and doubtless molasses could be utilized for this purpose much more extensively than is the case at the present time.

Muds (*or press-cake*).—This by-product contains all the solid impurities thrown out of the cane juice by liming and heating. When these impurities are allowed to subside (or settle), they are drawn off as a sludge (mud) which may subsequently be pressed in filters, whence it becomes converted to a cake (filter press-cake). The newly introduced suction filters also deliver a soft cake consisting of the original mud to which has been added a proportion of fine bagasse.

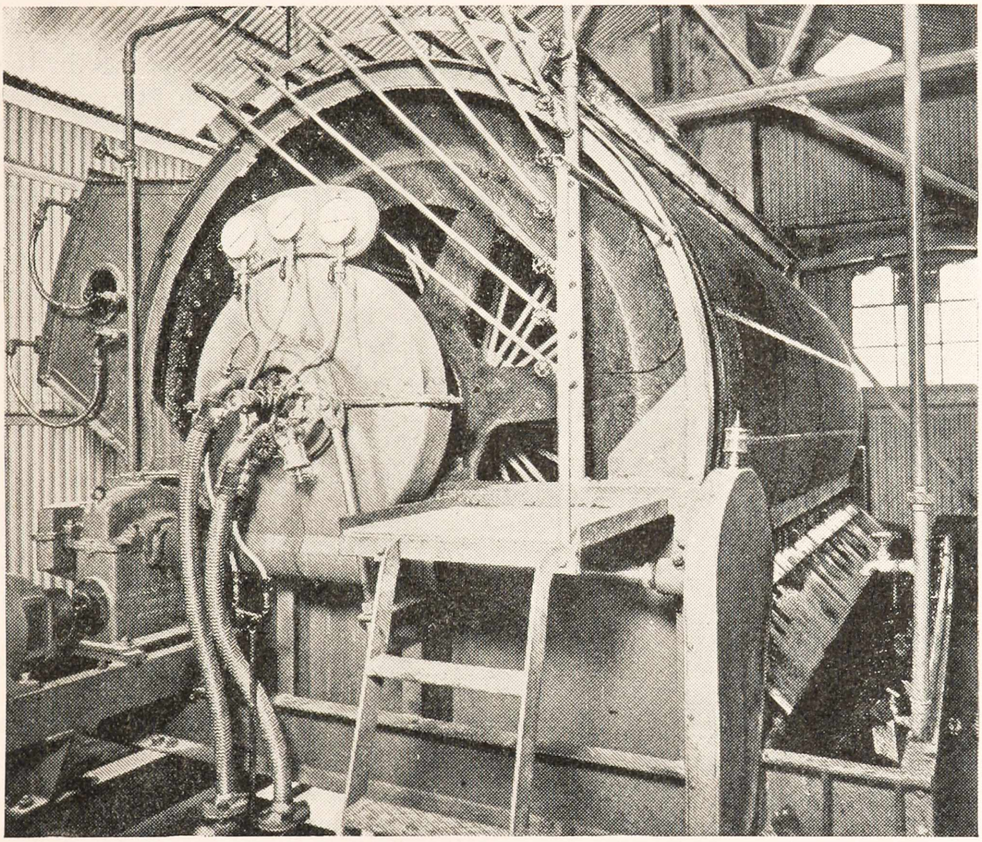


FIG. 87.—Showing a rotary suction filter now used for extracting juice from mill muds. The cake so formed has a definite agricultural value.

Reference to the table above shows that over 15 per cent. of the major plantfoods contained in the cane crop finds its way to the muds, and the phosphates are noticeably concentrated in this by-product. Many farmers have discovered the excellent results following an application of filter cake at the rate of 5 to 10 tons per acre. In addition to its plantfood content, the cake is rich in organic matter, which is readily converted to humus in the soil, and serves to improve the physical condition of the land. In this process it is assisted materially by the presence of the lime

which is added in the clarification process. Muds, as discharged from the subsiders, while containing the same valuable compounds as were discussed for press-cake, are rather too wet to enable them to be handled economically. As 90 per cent. of their bulk is water, it does not pay to transport them over long distances. This difficulty may be overcome by discharging the muds into trenches with sandy bottoms. These permit the removal, by seepage, of the excess water, and provide a final product similar to press-cake.

Bagasse.—Though the bulk of the bagasse is burned to provide power for the mill, certain factories are to-day embarrassed with an excess of this by-product, and many growers are prepared to convey it to their farms, should its value warrant such a procedure. Unfortunately, this bulky material is so relatively poor in plantfoods, and contains so much organic matter of a resistant nature, that it does not rot readily in the soil; its immediate value is therefore so low as to render the treatment generally ineffectual.

Ashes.—When burnt, all the nitrogen in the bagasse is lost in the flue gases; over one-half of the nitrogen which leaves the farm is thus destroyed. But the furnace ashes contain the bulk of the phosphate and potash of the cane, though not in a readily soluble condition; it is problematical whether the value of this by-product would warrant transportation to any but neighbouring fields, except at those mills which utilize molasses as a fuel. Under these conditions the plantfood content of the ash is very substantially increased, notably in potash, and such furnace ashes have been employed to great advantage on certain potash-deficient and eroded soils. Their use can be definitely recommended wherever it is necessary to add large amounts of plantfood to the land at low cost to the farmer.

CONCLUSIONS.

From the preceding discussion it will be evident that canegrowers might devote closer attention to the better utilization of molasses, mud (or filter cake) and certain of the mill ash for agricultural purposes. It should be the aim of all good farmers to maintain the fertility of the land at the highest possible level, and to do this as economically as possible. If the farmer can apply the desired proportions of phosphate or potash more cheaply in the form of muds or molasses, then money can be saved in purchasing the balance of the essential plantfoods in the form of artificial manures. However, the grower should seek the guidance of the Bureau officers in advising him of the correct method of calculating the balance for his particular soil; and if he is in doubt regarding the composition or true value of any mill by-products, it is a simple matter to submit a sample of the material to the Bureau, when it will be analysed and reported upon free of charge.

It might be mentioned, in passing, that heavy applications of muds, molasses and ashes have achieved extraordinary results when applied to hillside lands where much of the surface soil has been removed by flowing water (*see* Chapter on Soil Erosion). The incorporation of large amounts of nutrients in this manner provides a speedy means of adding fertility to the food-deficient subsoil which has become exposed.

Chapter X.—SOIL EROSION.

INTRODUCTION.

Very often one notices, in areas where the land surface possesses an appreciable degree of slope, that the cane on the crown of the hill is poor and unthrifty in appearance, while at the bottom of the slope the crop is far heavier than that on other portions of the block. The farmer understands clearly why this is so, for he knows that in times of heavy rainfall the water which runs off the land surface carries with it a greater or less amount of surface soil and deposits it lower down the slope. In spite of this all too common evidence of soil "washing" under these conditions, it is surprising that so little effort is exerted to check the effects of the process, which is by far the greatest enemy of permanent agriculture, and one of the most potent factors in the wastage of national resources.

Fig. 88.—Showing the manner in which a gully is forming in a hillside canefield.

Fortunately, the major portion of the caneland area of Queensland is relatively flat, so that run-off water flows over the soil at a relatively slow rate, and therefore removes little material in the process. But in certain districts are substantial areas of hillside slope where this is far from true, and many fields of valuable land are being rapidly deprived of their fertile surface soil. The Childers and South Johnstone districts provide abundant evidence of this effect on red volcanic hillsides of what were in their virgin state areas of very high fertility.

It should be appreciated that the forces of soil erosion are at work even where there is little visible evidence of the process in the form of gullies or gulches. Indeed, though the latter type is by far the most

spectacular, it is not the most important form of erosion. So-called "sheet" erosion, whereby the general run-off from the hillside takes place in the absence of well-defined watercourses, is able to effect even more damage over a period of years, and it affects the entire land area. It may be concluded that erosion is at work on all fields where heavy rains cause excess water to flow from the land at an appreciable rate. When the farmer recognises this fact, any effort which he is able to exert in preventing this damageable influence will be well repaid.

CAUSES OF SOIL EROSION.

When the land carries a protective covering of scrub or jungle growth, natural factors combine to minimise erosion effects. The exposed large roots, tree trunks, and mulch of fallen leaves and twigs do much to obstruct and check the flow of water, and the slower the rate of run-off the smaller is the load which the water can carry. Moreover, water flowing over a surface mulch of vegetation obviously does not wash away the soil which lies below and is protected by it. In its natural state—before man has taken a hand in modifying and compacting the subsurface layers by the use of tillage implements—the soil is highly porous and open in character, so that its capacity to absorb large quantities of rainfall at a reasonable rate is at a maximum. Indeed, in the discussion which follows, it will be found that methods of erosion control are to a large extent fashioned on an attempt to restore something of the conditions existing in the virgin, untilled soil.

With the removal of the jungle growth and the destruction of the surface leaf mould, two important factors retarding the rate of soil run-off are removed. In addition, the elimination of the trees and vines removes a factor which was instrumental in utilizing large quantities of soil moisture, through root absorption, and the soil is, therefore, not so thoroughly dried out between rains, and does not possess the absorptive capacity of the virgin land.

All these factors conspire to promote soil removal, and the position is aggravated by subsequent implement operation. It is well recognised that, while these aids to crop production result in the breaking up or loosening of consolidated soil to a greater or less depth, they invariably tend to introduce a compacted layer just below their range of influence. This "pan" is a serious obstruction to the ready absorption of rainfall; the net result is that in times of heavy falls, the loose surface layer formed by the particular implement rapidly becomes saturated with water, and eventually may flow down the slope in mass. Finally, continuous cultivation methods so common to cane production, result in the speedy decomposition of soil humus; this we have seen is one of the most important agents in retaining the soil in a good physical state, in avoiding rapid compaction, and rendering excess cultivation unnecessary.

FACTORS AFFECTING THE RATE OF EROSION.

The major factors affecting the intensity of erosion are—(*a*) soil type, (*b*) slope of the land, (c) amount and rate of rainfall, and (*d*) farm management methods.

(*a*) Sandy soils are, in general, least subject to erosion, since they are capable of rapid absorption of water. But should conditions result in the creation of a fully-saturated sandy soil, the absence of binding material permits it to be carried down a slope at a very rapid rate;

again, the coarseness of the particles may cause it to be deposited before it has travelled any great distance.

Heavy clay soils are more subject to gradual wearing down by water, but the strong cohesive forces which exist in such soils offers great resistance to loosening.

The soils most liable to erosion are, however, the intermediate class known as loams. When saturated with water they may move off in large masses due to their plastic nature. A loam rich in organic matter possesses advantages over those not so favoured, for this important soil constituent promotes more complete water absorption, while acting also as a mechanical obstruction due to its fibrous character. Unfortunately, few cane soils could be classed as rich in humus.

The presence of gravel and stones is sometimes helpful in preventing erosion, as they are themselves moved with difficulty; they also offer resistance to the free flow of water, and definitely protect the soil which lies beneath them.

Fig. 89.—This once-fertile cane land has been rendered worthless due to gully erosion.

(*b*) The steepness or "gradient" of the land has a very direct and obvious influence on the degree of erosion experienced. While silts are removed even by water flowing over relatively level land, the carrying capacity of flowing water increases at a very rapid rate with increased slope. This is very apparent when we study the rate of gully formation in a field. A series of measurements which were made to determine the influence of slope showed that, while 8,000 lb. of soil were removed annually from an acre of "level" soil, the rate of removal was doubled where the gradient was 1 per cent., and trebled where the slope was between 2 and 3 per cent. Steep slopes also affect the relative amounts of moisture absorbed and shed by the land.

The nature of the surface of the soil is one of the greatest factors in determining the extent of erosion, and is indeed one of the major considerations in devising control measures. This factor has been discussed in referring to land in the virgin state.

(*c*) It is readily evident that the rainfall rate is one of the potent factors in erosion. Heavy and rapid downpours inevitably cause greater

removal of soil than an equal amount of rain falling over a longer period. This is due to the time factor which is involved in the moisture absorption rate for any soil, and the soil removal influence is thus bound up in the amount of run-off water. The state of the soil at the time a heavy downpour is experienced—whether it is relatively dry or already water saturated—is an important consideration. Heavy rains themselves beat and compact the surface soil layer and destroy in some degree the natural absorptive capacity of the land. In the coastal regions of Queensland, with their recurrent tropical deluges, the effects of erosion are widely evident even on relatively gentle slopes.

(*d*) The character of the crop to which the land is devoted has a very marked bearing on the degree of erosion experienced. The following series of figures obtained from studies conducted in the middle west of the United States of America is very interesting in this connection:—

Soil Treatment.	Percentage of rainfall which ran off.	Total weight of soil removed per acre per year.
	Per Cent.	Tons.
Not cultivated	49	30
Ploughed 4″ deep	31	36
Ploughed 8″ deep	28	31
Grass sod	12	$\frac{1}{4}$
Wheat each year	25	6
Maize each year	27	16

The slope of the land was slightly less than 4 per cent., and the annual rainfall varied from 24 to 50 inches over the duration of the experiment (6 years). Certain features of these results are worthy of note. Firstly, erosion was greatest on the loose, ploughed soil without crop. Secondly, the presence of a growing crop reduced the loss, and this influence was greatest with the crop which afforded the most complete cover. Maize—which might be compared with sugar-cane in this regard—reduced the erosion loss by one-half, wheat effected a reduction of five-sixths, while with grass sod an insignificant amount ($\frac{1}{4}$ ton) of soil was carried away. In passing, attention should also be drawn to the loss of water due to run-off which occurred under the various systems of husbandry. The rate of soil removal on a well-tilled slope is commonly evidenced in our Queensland cane areas, when a deluge of rain is experienced during the planting season. How often the farmer awakes to find his soil and plants washed down to the low end of the block!

THE PREVENTION OF EROSION.

From the preceding discussion it may be concluded that soil erosion is caused by water running from higher to lower levels over the surface of the ground. Erosion control therefore consists in decreasing or diverting the run-off, or both. The possible methods are—

(1) Reducing the run-off by making the soil more readily absorbent.

(2) Keeping the soil covered; a good vegetative cover also slows down the run-off and causes more water to be absorbed.

(3) Holding and diverting the water along courses having such a gradient that the erosion damage is negligible. This principle is employed in terracing.

(4) Conveyance of water from higher to lower levels in artificial channels. This principle is generally applied in disposing of concentrated run-off from fields, and in checking deep gullying.

These several preventive methods will be discussed in some detail.

1. The absorptive capacity of the soil may be improved by subdrainage. The growth of deep-rooted crops—e.g., lucerne—will open up stiff soils and provide channels through which the water may pass. Deep ploughing and subsoiling or grubbing will also assist in increasing absorption. In ploughing on slopes, the furrow slice should always be thrown up-hill, by the use of a reversible hillside plough. Land left in this condition will always absorb more water than where the furrow slices are thrown down-hill. Contour ploughing is obviously better than ploughing up and down the slope for similar reasons. All methods of humus restoration are to be encouraged, slow though the process may be; a soil rich in organic matter will remain open and make for more complete rainfall absorption.

Fig. 90.—Showing the manner in which erosion commences, when heavy rains follow planting and wash away loose soil and plants.

2. Unfortunately, the canegrower has little opportunity for keeping his land covered. Where crop rotation is the vogue, the farmer may keep his land under grass cover for a proportion of the rotation period; and the steeper the slope of the land the greater the proportion of the rotation during which grass cover should be kept. The canegrower has, however, two opportunities of doing something in this regard; during the fallow, a green manure crop should invariably be sown;

where serious erosion losses are encountered, trash should *never* be burned but left on the land surface to serve as a mulch. The benefits of trash conservation are twofold—(*a*) the avoidance of ratoon cultivation leaves the soil undisturbed and reduces the rate of subsurface packing; (*b*) excess water is shed by the trash layer instead of by the loose soil, and, therefore, a sediment-free run-off replaces the normal sediment-laden stream. On certain farms in the humid northern cane districts, this practice is being employed systematically with very good results. Relieving of the trash from the stools promotes a more rapid ratooning, and facilitates the application of both mixed fertilizer and sulphate of ammonia.

Experience shows that land of greater slope than 5 per cent. should *never* be devoted to cultivated crops continuously; where the slope reaches 10 per cent. cultivated crops should occupy the land only during a small fraction of the rotation period, while land of more than 15 per cent. slope should be kept in permanent pasture. From these data it is evident that much land which is being cultivated at the present time will be *completely useless* in a few years. Unfortunately, no means are available whereby the farmer may be obliged to devote his land to those crops for which it is suited, and thus avoid the national calamity of denuded hillsides of waste land. Certainly this is not a question for determination by the individual.

3. Where the methods hitherto discussed are not adequate or suitable for the purpose of effecting erosion control, the farmer must resort to terracing his land. Such a suggestion is generally dismissed by the farmer as something both costly to carry out and difficult to deal with. A careful study of the accompanying notes will show, on the contrary, that terracing may be effected at very little cost, while its presence is scarcely noticed during subsequent cultural operations.

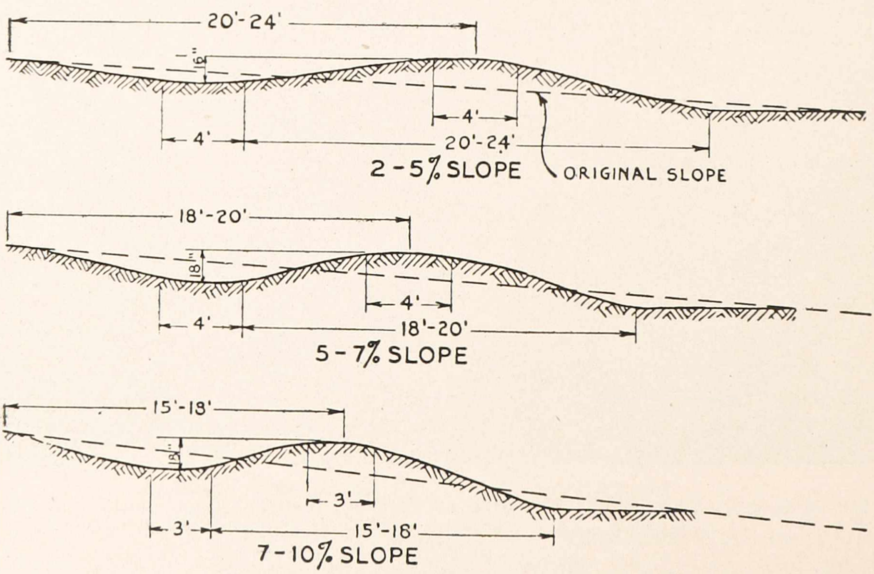


Fig. 91.—Illustrating the manner in which the dimensions of the terrace are modified to conform with the slope of the land.

CONSTRUCTION OF TERRACES.

The terrace is a flat ridge of earth like a steeply-graded road or an extra large back-furrow, from 15 to 25 feet wide at the base, and built *almost* on contour lines around the slope. Above this ridge is a flat,

broad channel. The crest of the terrace is 15 to 18 inches above the bottom of this channel. Terraces control the run-off, because they are spaced in a series like steps down the slope, each taking its share of water before the total quantity becomes large enough to do damage. The water which each traps is carried in a broad slow-moving stream to the side of the slope without damage to the field. This slow movement keeps the water in the field for a longer time, causing more of it to be absorbed into the land, and reducing run-off and loss of soil by erosion. Reference to the accompanying sketch (Fig. 91) together with a detailed description of the process of terrace contruction should make these points clear.

Terraces are constructed in such a direction across the slope of the land that they provide a sideways fall of not more than 6 inches in 100 feet. They are spaced so that each will take care of the water which falls between it and the one above; they must be close enough together so that the run-off water from average storms will not have an opportunity to descend in small rivulets between the terraces. Where the slope is slight, practically all sediment carried to the terrace under abnormal conditions will be deposited immediately. The most suitable distance between terraces is governed by the slope of the land and the soil type. As a rule, there should be a vertical fall of from 4 to 6 feet between terraces on land with a grade of from 5 to 10 per cent. A greater vertical distance should be allowed where the slope is greater.

The most suitable distance between terraces is shown in the following table: —

Slope of Land.	Vertical Drop between Terraces.	Distance between Terraces along Slope.
Per cent.		Feet.
3	3′ 0″	100
5	4′ 3″	86
8	6′ 3″	78
12	7′ 0″	58

The gradient along the terrace is also governed by the length of the terrace and the natural slope of the land; the following table offers a useful guide in this respect:—

Length of Terrace.	Gradient per 100 feet along Terrace where Land Slope is—		
	5 Per Cent.	10 Per Cent.	15 Per Cent.
Feet.	Inches.	Inches.	Inches.
0 to 300	½	¾	1
300 to 600	1	1½	2
600 to 900	2	3	4
900 to 1,200	4	6	7
1,200 to 1,500	6	..	..

In staking out the terraces a home-made level is useful (Fig. 92). It is constructed in such way that one leg is shortened or made adjustable, so that the correct fall is obtained when in the "level" position, as shown by the bob or spirit level. Thus if the span be made 16 feet 8 inches six steps will be required per 100 feet of terrace; hence, to strike a fall of 6 inches in 100 feet, one leg should be made 1 inch shorter than the other.

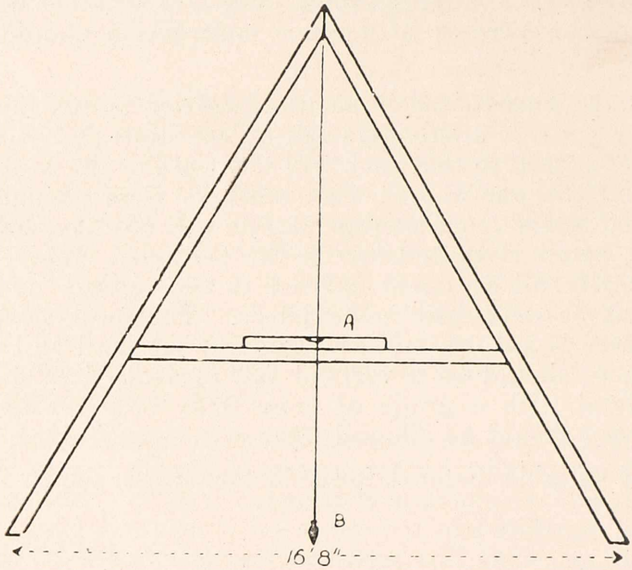


FIG. 92.—Illustrating the home-made leveller for use in laying out terraces. Either spirit level (A) or bob (B) may be used.

The first step in the construction of the terraces is to find a suitable outlet for the water which will be discharged at either end of the terrace. This is most important. A well-sodded pasture is best. Care should be taken that any gully into which the water is discharged is protected against erosion, using saplings or rocks where necessary (Fig. 93), while at times earth dams may be necessary. The point at which a terrace crosses an intermediate small gully must be higher and stronger than at other points to eliminate the danger of the water breaking through. The top terrace is made first, and should be built up sufficiently high, so that water from higher up will not collect and break across it before it has settled. An ordinary swing plough may be used to mark out the line of stakes on the terrace; the stakes may then be used in setting out the next one below. It is important to exercise care in laying out the terraces accurately.

The terrace is built up first by means of a team and plough, and later by the use of a light road grader or V-shaped drag. Very little ploughing is necessary in light soils. It is customary to throw together six or eight furrows, and then push the soil towards the centre by means of the grader. This process is continued until the top of the terrace is 12-15 inches higher than the lowest point above the terrace—that is, in the water channel. When completed the terrace should be fairly compacted, and no low points should be left. It is important to build sufficiently highly over low places or small gullies.

During subsequent ploughing and planting operations, the contours should be followed; if the slope is less than 8 per cent., and the terraces are well established, they may be ignored in all cultural operations.

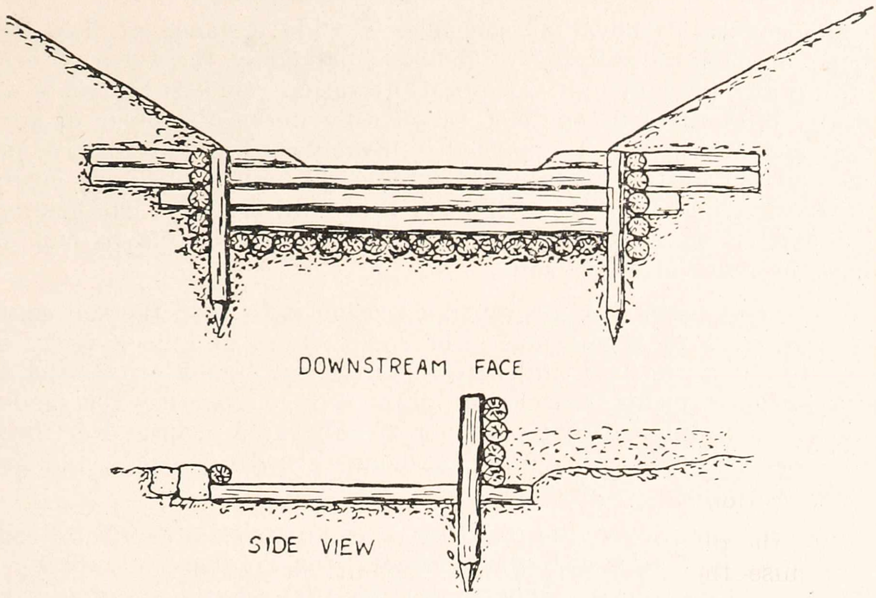


FIG. 93.—A suitable type of log dam which may be built across a gully. The apron of timber effectively prevents erosion by the falling water.

When crossing the terace it is an advantage to plough slightly shallower so that the bank is not weakened early in its lifetime. It is advisable to pay careful attention to the terraces during their first year, so that any break may be repaired as it forms. It is best to throw a little soil on to the terrace when ploughing, and the channel on the upper side of the ridge must be kept clear. For safety sake, the land should first be devoted to grass or to a cover crop of peas or beans to give it the best opportunity to consolidate.

Although terracing has not been exploited in the Queensland cane areas, it is a practice worthy of the closest consideration by growers who are farming high slopes. The cost of the work in the American states is about 10s. per acre, which is certainly not excessive. The farmer should take care that the work is carried out after the risk of heavy rains is past—that is, during the autumn or winter months. The terraces will then have an opportunity of settling down by the late spring, when a cover crop of legumes may be planted to protect the terrace during its first wet season.

CURE OF EROSION DAMAGE.

From what has been said it will be apparent that the direct cause of destructive erosion is, on the one hand, soil disturbance, which destroys the binding forces operating under natural conditions, and on the other hand, the force of running water tending to move it. Removal of natural vegetation also tends to increase the quantity of run-off. The formation of gullies may usually be traced to the creation of a direct fall for run-off concentrated at that point. Gully-cutting must be checked by decreasing the fall and cutting power of the water until it becomes negligible. This may be done by diverting the water to a fresh channel, by providing an artificial channel at the fall, or by

raising the level of the gully floor by means of soil-saving dams. This reclamation work should commence at the head of the gully, while the lower part can later be reclaimed by additional dams, if the value of the land warrants the cost.

The general removal of soil over a wide expanse of field (sheet erosion) or shallow gullying of fields is primarily the form of erosion attending any form of cultivation. Cultivation removes the roots which naturally bind the soil together, by turning under the layer of surface organic matter which helps markedly in increasing the absorptive power of the soil, by destroying the soil humus through continuous cropping and exposure, and by making the soil loose and friable. The lastnamed also assists in water absorption, but when water begins to run off it hastens the removal of the soil.

The surest method of preventing erosion is to keep the soil continuously covered with vegetation. For steep slopes and poor rocky soils, forest growth is the best and safest plan. For better soils, capable of producing good yields, permanent grass is recommended for moderate slopes with but intermittent planting of cultivated crops. Fertilization of such pastures will assure more luxuriant growth of grass, and hasten the rate of fertility restoration.

For the canegrower, the planting of cane varieties of strong ratooning qualities will minimise the necessity for frequent ploughing and replanting of the block. Liberal fertilization should be employed to ensure a succession of profitable ratoon crops, and, as already pointed out, trash conservation will avoid excessive disturbance of the underlying soil, and prevent washing. Where weed growth does occur in ratoon crops, it may be worth while considering spraying methods of control in preference to surface cultivation.

If erosion has already reduced the fertility of the land to the point where it is not possible to produce even a moderate plant crop, speedier means of building up the soil plantfood supply are called for. This has been achieved with a marked measure of success by many South Johnstone growers by the application of heavy dressings of mill refuse to the soil. Muds and filter cake, molasses, and mill ash (where molasses is used as fuel) are excellent in this regard, and serve to confer a vigour of growth upon the plant crop which may be sustained in the subsequent ratoons by the consistent use of moderate dressings of artificial manures. Sulphate of ammonia is particularly important in this respect, as the loss of the surface soil robs the field of the bulk of its nitrogen supply.

Finally, many soil erosion problems are not individual but community concerns, which can only be tackled and solved through the concerted effort of all concerned. This must usually be achieved through the intervention of an independent authority; this course must inevitably follow the full realisation of the seriousness of soil erosion from the national standpoint.

Chapter XI.—CANE HARVESTING AND MATURITY TESTING.

Although the farmer produces *cane,* the marketable commodity of the industry is *sugar*: and as the farmer is well aware, the value of his cane bears a direct relationship to its sugar content. Indeed, when the legislation governing cane prices was first framed, due attention was paid to the importance of growing only "sweet" canes; and the scale of values based on sugar content provides a bonus on all cane supplied to the mill, which contains more than the basic amount of 12 per cent., while penalising cane in like manner when its sugar content falls below this value.

The net effect has been to eliminate virtually all canes of "low" sugar content wherever a suitable sugar-rich substitute could be found. Naturally this is not always possible, as certain canes are often propagated because of some special virtue, such as resistance to disease or drought, and a moderate sugar content may then become a matter of secondary importance: but it is the aim of the plant breeder to produce new varieties which combine high sugar content with other essential favourable characters.

Since the introduction of the Cane Prices legislation in 1915, a steady and persistent improvement in quality of cane may be traced until the present time. If we review the average tons of cane required to produce a ton of sugar in Queensland for 5-year periods, we find—

Period.	Tons cane per ton 94 n.t. sugar.
1913-17	8·60
1918-22	8·04
1923-27	7·55
1928-32	6·95
1933-37	6·98

Of course other factors than cane quality have contributed to this improvement; such are superior mill work, and the shortening of the crushing season, while better cultural methods and the more adequate and intelligent use of fertilizers have also exerted their influence.

At the same time, it must be admitted that there still exists a substantial margin for improvement: and though the canegrower plans in a general way to produce crops which mature at various stages of the harvesting season, there is still a large degree of guesswork in determining the order in which his several fields should be harvested. It is therefore proposed to discuss the several factors which influence maturity, the manner in which the farmer can employ these factors to his advantage, and finally the ultimate and only reliable means of actually determining the state of maturity of a cane crop.

FACTORS INFLUENCING THE MATURITY OF THE CROP.

1. Variety.

Cane varieties may be classified in a general way into three groups:—(*a*) early maturing canes, (*b*) mid-season canes, and (*c*) late maturing canes. The first and third groups contain relatively few members

amongst the better varieties propagated in Queensland on a commercial scale: by far the largest number falls within the "mid-season" class. Of early maturers, Clark's Seedling and H.Q. 285 are amongst the best known: B. 208 and S.J. 2 are also moderately early—that is, they attain a high C.C.S. content relatively early in the harvesting season. E.K. 28, S.J. 4, and Co. 290 are the best known of the late maturing canes, while Badila, Q. 813, M. 1900, and P.O.J. 2878 are well-recognised representatives of the mid-season class.

In general, each cane variety shows a progressively increasing C.C.S. content through the winter and early spring months, eventually attains a peak of sugar content either in August, September, or October, and then shows a progressive decline. Here again there is a distinct varietal influence, for whereas certain canes (such as Badila) possess the ability of "holding" their C.C.S for a substantial period, others (notably H.Q. 426 in drier areas, and E.K. 28) are found to decline in quality at a relatively rapid rate, after the peak of maturity is passed.

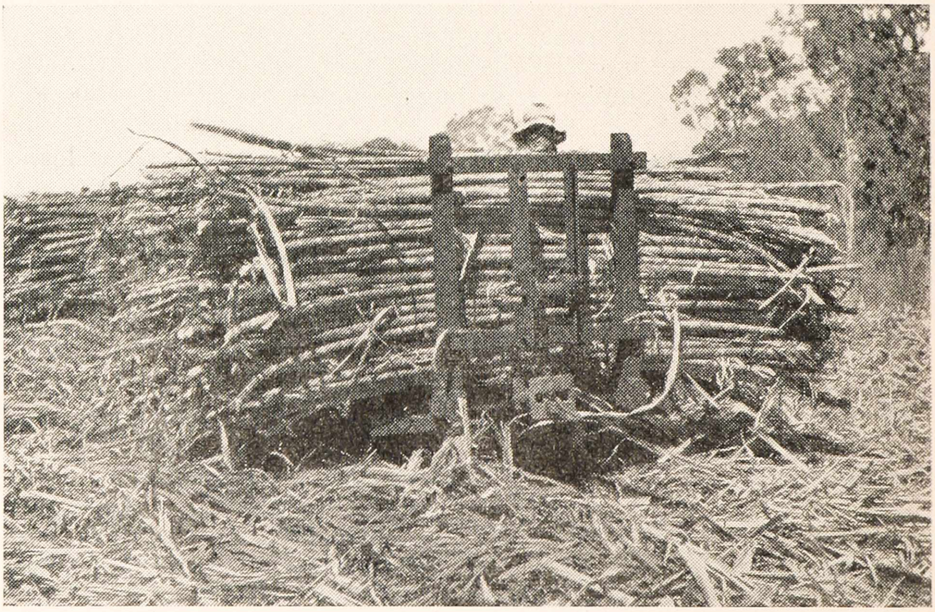


Fig. 94.—Loading long, clean stalks of cane on mill trucks, in the canefield.

The greatest demand amongst canegrowers to-day is for a wider selection of early maturing canes. This would enable them so to regulate their plantings that they would have a sufficient area of early maturing cane to maintain their harvesting quota for say—the first 6 weeks of the crushing, after which they could take off their mid-season varieties and finally, their late maturers over the concluding weeks of the harvest. The production of early maturing seedlings is not a simple task, but fortunately there exist other methods whereby the maturity of the crop may be regulated in some degree by the farmer: these will be discussed in due course.

2. Age of Crop.

Next to varietal characteristics, the age of the crop is the most important factor in regulating the time of maturity of a given variety. From the time millable cane makes its appearance in the field of growing

cane, the process of sugar storage begins, and progresses until the cane attains its peak of sweetness. Experience shows that the influence of the actual age of the cane—that is, the period during which it has been in existence in the field is of considerable importance in governing the final C.C.S. content attained by a crop at harvest time. Therefore a crop of mid-season variety planted in the month of March will, in general, possess a higher sugar content in the month of July of the following year than a crop of similar cane not planted until August. For similar reasons, well irrigated crops of normal dimensions will ripen—and generally attain a higher C.C.S.—than cane produced on similar land without artificial water application.

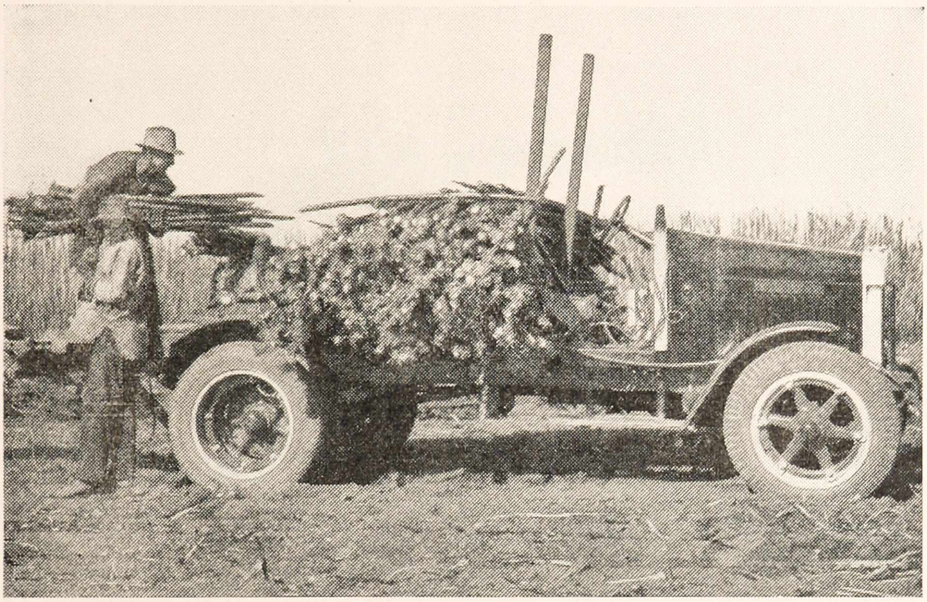


FIG. 95.—Where portable tramline is not provided, the motor lorry is very useful. It eliminates also undue carrying of cane bundles.

The effect of crop age is greatly exaggerated in the case of a two-year-old (''standover'') crop. At the conclusion of the first season of growth, such a crop will attain a state of maturity, but if not harvested, the sugar content will decline with the advent of early summer rains and favourable growing conditions; but it is found that practically all such crops will, during the second winter season, attain their peak of maturity in July or August, even where the variety is normally a late maturer. The value of standover cane for early harvesting is generally appreciated by canegrowers in Southern Queensland, where such an excellent standover cane as P.O.J. 2878 is available. There exists the danger, however, of retaining more than sufficient two-year-old cane for early harvesting and the excess becomes over-mature before it is cut. Such an occurrence is just as unsatisfactory to the grower as the harvesting of immature cane, whereas it is generally more difficult for the mill to treat than an immature crop of identical sugar content. Again, however, the grower is in a position to delay the maturity of his crop by the judicious use of fertilizers, as will now be discussed.

3. Use of Fertilizers.

It is now well recognised that the individual constituents of mixed fertilizer exert a definite influence on both the maturity and the C.C.S. of the crop. The plantfood *nitrogen* possesses the property of delaying crop maturity, and if used in excessive amounts, may actually lead to a substantial depression in the C.C.S. ultimately attained. *Phosphates* exert little influence on sugar content, though the evidence suggests that they bring about a slight reduction. *Potash,* on the other hand, definitely influences both the period of maturity and sometimes the C.C.S. finally attained by the cane; moreover, it is frequently found that potash applied to a soil which shows no benefit from such treatment, insofar as cane yield is concerned, may cause an appreciable improvement in the state of maturity of crops harvested early in the season. For late-harvested cane, the effect may be even deleterious, in that it will likewise hasten the period of sugar-loss due to over maturity.

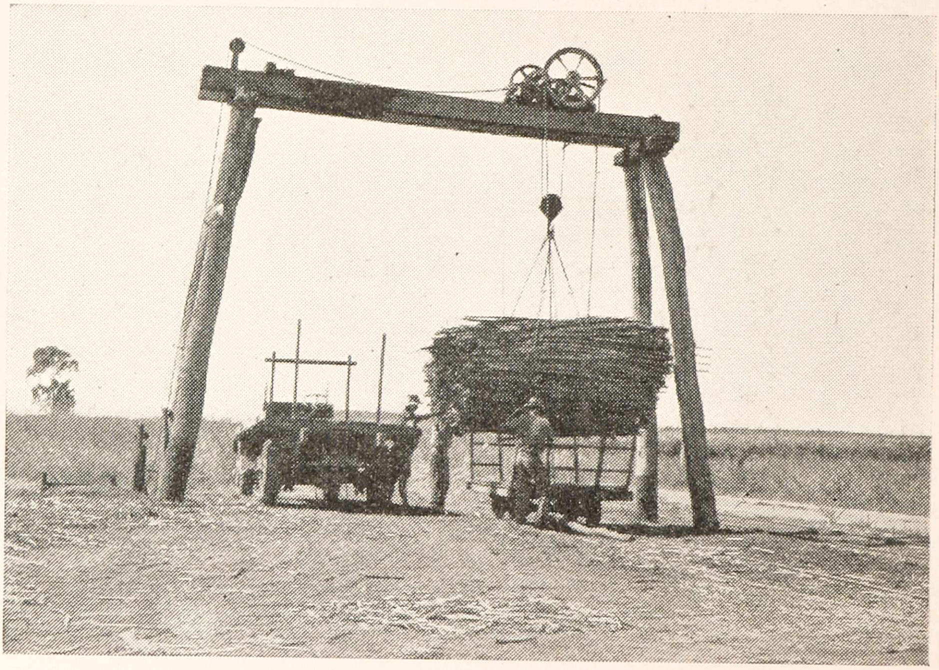


FIG. 96.—Transferring cane from motor lorry to tramline truck.

The low C.C.S. content of rankly grown canes harvested from virgin soils is usually due to the excess of available nitrogen supply to the crop. In general, nothing can be done by the farmer to correct this condition, except by eliminating all nitrogen from the fertilizers he applies, until this transitory period has passed. Thereafter, applications of 2 or 3 cwt. of sulphate of ammonia per acre will result in no harmful influences: but dressings of 5 or 6 cwt. per acre are often responsible for depressed C.C.S. content. Other things being equal, the earlier the nitrogenous manure is applied, the less objectionable will be its influence in this respect. That is one reason why the Bureau recommends consistently the early application of sulphate of ammonia top-dressings. On the other hand, a late (though not necessarily heavy) application of this manure to a standover crop—say during January or February of the second growth season—will so delay the maturity as to make it possible to defer harvesting until September or perhaps

even later without any serious loss in C.C.S. Southern canegrowers should bear this in mind, for it will also tend to reduce substantial losses from those troubles of over-maturity such as red rot and rind disease.

4. Influence of Irrigation.

A cane crop which receives consistent applications of irrigation water, as required, throughout its growth period, will naturally make a more normal growth than one which is subjected to the vagaries of the weather. Moreover the average "age" of the actual cane, as discussed, is greater than that of a similar crop grown under conditions of natural rainfall; and provided the water supply is gradually tapered off, the desired crop may be produced by say—late April, and the succeeding winter months will be sure to build up the sugar reserves and the C.C.S. of the crop.

5. Seasonal Effects.

The average C.C.S. of the cane crushed in a particular district is markedly influenced by the weather conditions under which the crop has grown and matured. It will be evident, from the foregoing reasoning, why a crop which has been favoured by good spring and summer rains, followed by a relatively dry autumn, will yield a higher C.C.S. than one which has suffered from moisture deficiency during its early growth months, and which has made the bulk of its growth during the late summer and autumn months. The weather conditions obtaining during the harvesting season may also influence the C.C.S. of the crop. It is well recognised that the C.C.S. of the cane may show a rapid improvement in a dry spring, simply because the evaporation of moisture from the cane leaves proceeds at a more rapid rate than the absorption of moisture by the crop roots. In other words, the improvement is accompanied by a loss in crop weight, and the yield of sugar per acre is not affected. However, should rain fall on such a field, the parched crop will greedily draw on the soil moisture, restoring the weight to the cane, but diluting the juice and lowering the C.C.S. as a consequence. Thus the farmer is troubled by erratic C.C.S. tests which are strictly speaking in no way related to maturity of the cane. Though, as pointed out, the influence of the drying-out factor does not produce more sugar per acre, it is of importance to the canegrower; for his harvesting costs are based on the weight of *cane*, while the value of the crop is governed by its *sugar* content.

6. Soil Type.

It is well recognised that there often exists a relationship between the soil type and the sugar content of the crop harvested therefrom. For example, alluvial soils—and notably those of a silty or sandy loam character—are known as "high C.C.S." lands; red volcanic soils, on the contrary, usually yield cane of subnormal sugar content. The influence of soil is probably complex—being affected by moisture supply, nitrogen, and potash availability.

The characteristic "low C.C.S." of cane grown on the red volcanic soils is probably associated with the potash deficiency which such soils frequently display. The results of potash trials conducted by the Bureau on lands of this type indicate very clearly that the judicious application of manures rich in potash (such as Sugar Bureau No. 3), will lead to a decided improvement in the C.C.S. of the cane at maturity.

MATURITY TESTING.

An appreciation of the several interrelated factors governing crop maturity will enable the canegrower to apply himself intelligently to a determination of the probable order in which his crops should be harvested for the maximum of financial benefit to himself. Thus he would logically harvest his early maturing varieties (or standover cane) first of all, while preference would be given to the cane which is most advanced in growth. He will also be influenced by the appearance of the cane crop—one with an abundant green top he would expect to be less mature than that with yellowed and shrunken foliage. A knowledge of past results from his various soil types will also tell him that, in general, the sandy loam blocks produce crops that mature earlier than his heavier or clayey fields. But there still exists a grave element of doubt unless his conclusions are based on something more definite and scientific in character. This something is provided by an adequately conducted scheme of maturity testing.

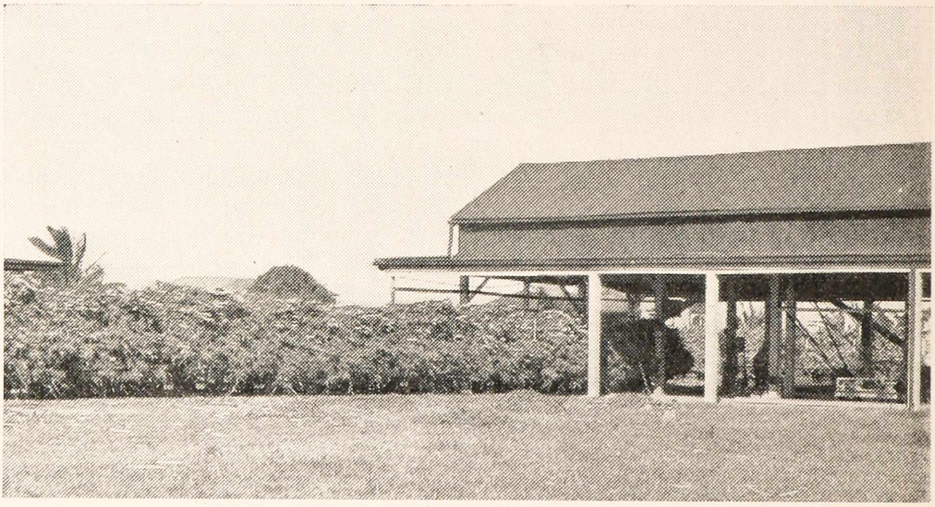


FIG. 97.—A supply of cane at its peak of maturity enhances both the return to the farmer and the recovery of sugar by the miller.

This project has been widely discussed in Queensland in recent times, and the essential tests have been reduced to their simplest and most effective terms. Briefly, the process consists in selecting from each field of cane a sample of stalks representative of the entire crop. If such stalks be subdivided into three portions of equal lengths—top, middle, and butt sections—and the corresponding portions be crushed together in a laboratory mill, three samples of juice will be obtained which will show, in general, substantially different composition on analysis. For immature cane, the juice from the butt sections will be richer in cane sugar and poorer in "reducing sugar" than that from the other sections. As the cane approaches maturity, the differences in juice composition gradually disappear; and the cane is regarded as mature when the juice composition is essentially uniform throughout the stalk. Thereafter, the cane becomes over-mature, which is shown by a juice from the top sections richer in cane sugar than that from the mid or butt sections.

The method thus resolves itself into the systematic selection of representative samples from all blocks, followed by sub-sampling, crushing, and juice analysis as outlined. Some farmers are tempted to essay the

project themselves, but such a course is not to be recommended. Doubtless, some guide is better than none; but the work is rather too specialised to be carried out with the desired degree of accuracy by the farmer. A well-planned campaign, executed efficiently, would not be a costly undertaking, and the results would amply repay those mill areas in which it is instituted.

FIG. 98.—Steamer loading raw sugar at a Queensland port. Though the farmer grows cane, he actually sells sugar, and for most profitable returns, all cane should be harvested at its peak of maturity.

In conclusion, a striking example of the order of maturity of a number of blocks on an irrigated farm on which only Badila was grown is provided by the results obtained from a maturity-testing campaign conducted a few years ago:—

Variety and Class of Cane.		Area of Block.	Date of Maturity.
		Acres.	
Badila	Plant Cane	10	10th August
	1st Ratoon	22	22nd August
	5th Ratoon	16	9th September
	2nd Ratoon	12	23rd September
	2nd Ratoon	12	7th October

This is a case where all fields could obviously not be harvested precisely at the point of maturity and maximum sugar content; but the tests show with certainty the *order* in which the blocks should be cut to avoid undue losses from the harvesting of highly immature or over-ripe cane.

Without the knowledge which the maturity tests provide, the farmer would scarcely be able to plan his harvesting campaign under these conditions.

Finally, the farmer should bear in mind that the cane which shows the highest C.C.S. on a selected stick sample is not necessarily the nearest to maturity. For a crop which by test is shown to be mature when the C.C.S. is only 12 should be harvested in preference to one showing a C.C.S. value of 14 if the tests demonstrate that the latter is still *improving* in quality.

Chapter XII.—CANE VARIETIES AND CANE BREEDING.

Even casual examination of a random collection of canes makes it evident that all sugar canes are not alike. They differ widely in colour of stem, thickness, habit of the foliage, sugar content, and many other important particulars. These different kinds are known as *varieties*, and the grower must understand the peculiarities of the available canes, so that he may employ only those varieties which are best suited to his conditions.

It is interesting to recall that, until the latter half of the nineteenth century, the sugar industry of the world was dependent on a mere handful of varieties. These had been transported from country to country by navigators and explorers, and they often received a changed name in the process, while sometimes they were reintroduced to the land of their origin as a different variety! The best known of the earlier canes were—Cheribon, White Transparent, Cristalina, Rose Bamboo, Bourbon, and Tanna. Due to continued propagation over many centuries they had deteriorated due to the influence of disease and pest attack. The sugar industry was therefore obliged to cast about for new varieties, with the hope of finding in their native habitat, canes which were hitherto unknown. Of interest in this connection is the expedition to New Guinea which was led by Tryon, an officer of the Queensland Department of Agriculture, in 1896. In the collection of new varieties which he brought back were several important varieties, which became valuable commercial canes. The chief of these was Badila, which is still the major variety in North Queensland.

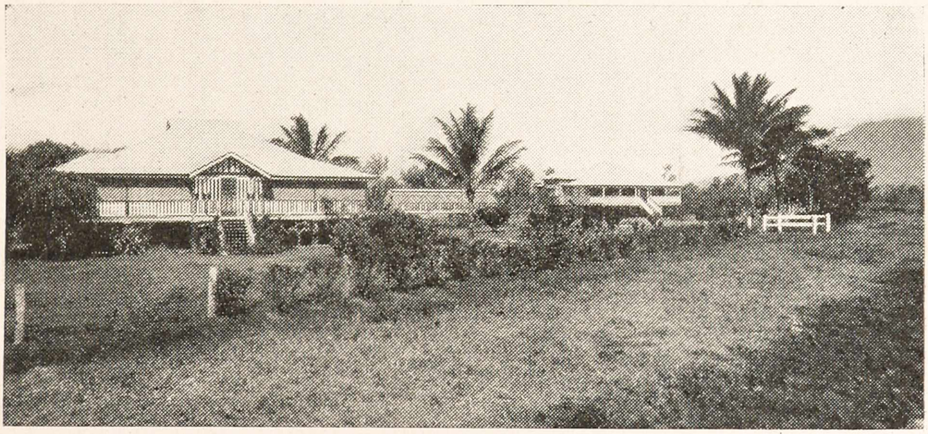


FIG. 99.—General view of the Northern Sugar Experiment Station, Meringa. Headquarters of the cane-breeding work of the Bureau.

Sugar-cane had for so many centuries been propagated by cuttings, that it was generally supposed to be incapable of producing fertile seed. But in the late eighties of last century, Bovell and Harrison in Barbados, and Soltwedel in Java, discovered independently that cane seed was produced under certain conditions, and that by planting this seed, new varieties of cane could be produced. This epoch-marking discovery was responsible for a new and vigorous policy of producing new varieties,

many of which were markedly superior to the old commercial canes: and the results of this work have exercised a tremendous influence on the subsequent history of the world's sugar industry.

In the field of cane variety production, Queensland workers were in the vanguard. The Queensland Acclimatisation Society raised cane seedlings as early as 1890. The best known of these is Q. 813, bred about 1906, which still occupies an important place in the planting programme of Mackay farmers. From 1901 to 1905, seedling raising was carried out by the Colonial Sugar Refining Company at their Hambledon Plantation, and here were bred the well-known Clark's Seedling (H.Q. 426), H.Q. 285, and H.Q. 409. With the establishment of the South Johnstone Experiment Station, the Bureau was able to institute cane breeding at that centre, in 1921. The best known of the early seedlings produced were S.J. 2, S.J. 4, and S.J. 7. The variety S.J. 4 is now a major cane in the Cairns district, while S.J. 2 is propagated in the Burdekin and Mackay areas, chiefly by virtue of its phenomenal sugar content.

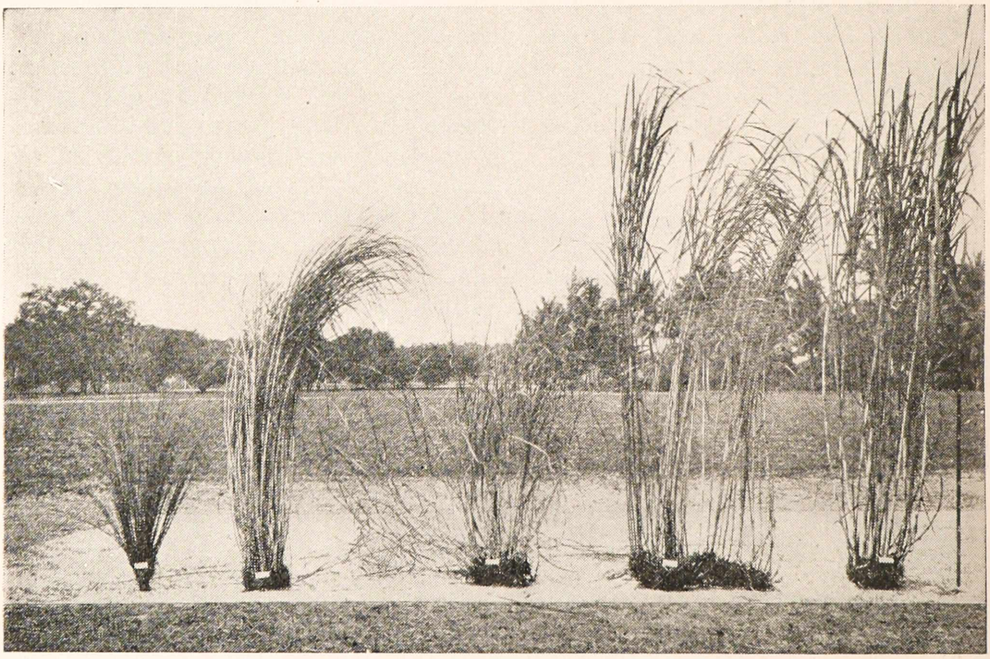


Fig. 100.—Illustrating the variations between different varieties of "wild" cane.

It is interesting to recall that the Java cane researches were inspired by the existence of a mysterious disease known as *Sereh,* which threatened the very existence of the sugar industry in that country. The varieties which had been propagated until that time belonged to the "family" of thick, juicy, sweet canes, often spoken of as "noble" canes. There exist other families of canes which differ markedly in certain important particulars, and which botanists place in a distinct class; they are popularly spoken of as "wild canes." They possess, in general, thin woody stalks, with little juice and sugar, but are of robust, vigorous habit, and often carry the important characteristic of resistance to certain major diseases. It then became the problem of the cane breeder to recombine the best qualities of the noble cane with the virtues of the wild species, in new and superior individuals.

The success of such a carefully planned and thoroughly executed policy is exemplified by the outstanding results which have been achieved in Java, and to a certain degree, in other leading cane countries.

The earliest Queensland efforts in cane seedling production were handicapped by the fact that the parent canes employed were all noble varieties; and though their progeny were often vigorous growers and rich in sugar, they were generally too "aristocratic" in their make-up, and could not withstand disease or thrive under other adverse conditions. Unfortunately, the policy of promiscuous importation of new varieties from all sugar countries, which was the vogue for many years, resulted in the inevitable introduction to Queensland of the world's major cane diseases. Unless the varieties available to the canegrower are able to produce satisfactory crops in the face of these scourges, the industry must languish. An example of the importance of disease has been given in the case of Java: but we have equally spectacular records much nearer home. The sugar industry in Southern Queensland was threatened with extinction on several occasions, due to widespread gumming disease in varieties susceptible to its attack. As recently as 1928 the industry in those parts was able to exist mainly through the propagation of disease-resistant canes which possessed otherwise unsatisfactory growth characteristics, and reduced yields were unavoidable. The entire aspect of the problem was changed by the introduction of varieties which were not affected by disease, and which, moreover, were superior in yielding capacity to the older standard canes.

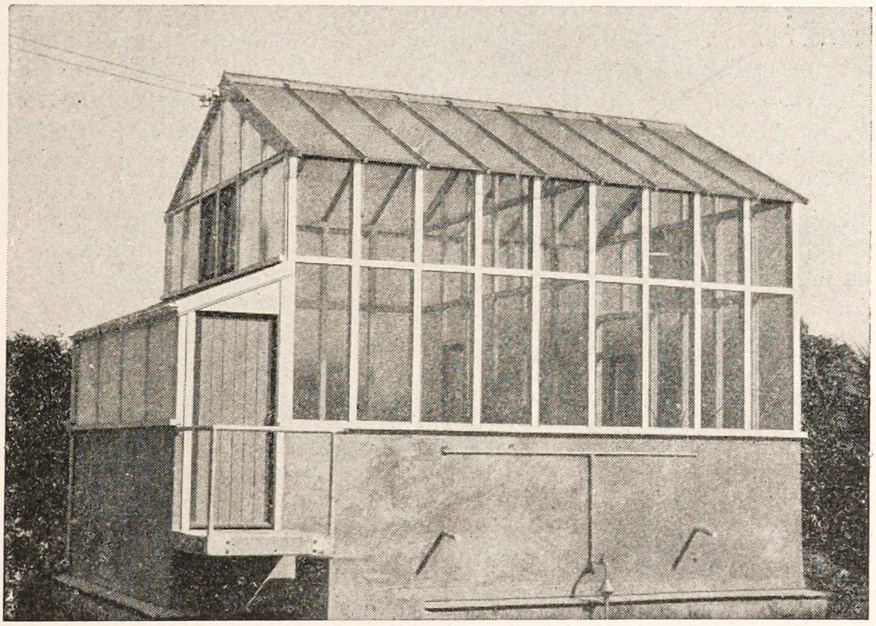


Fig. 101.—Quarantine glasshouse at Brisbane. All "imported" canes are grown for a year in this house to ensure freedom from disease, before they are transferred to the cane areas.

The cane breeding programme of the Bureau has therefore been recast, in recent times, with a view to introducing the characters for disease resistance in the parental matings. The introduction of the wild cane, *Glagah,* in Java provided canes resistant to Sereh disease, and it is a happy circumstance that the same wild parent confers

resistance to gumming disease and mosaic on its progeny. By breeding the wild and noble canes, hybrids were obtained which still suffered many of the disabilities of their wild ancestor, but were, nevertheless, disease resistant. A further cross-polination with a noble species yielded a superior cane, which, though perpetuating the character for disease resistance, was still too poor in sugar for commercial purposes. By a third "nobilization," as it was called, the desired varieties were secured. The most successful of these is P.O.J.* 2878, best known as the Java "Wonder Cane." This remarkable cane is so adaptable to a wide range of environmental conditions, that it occupied virtually the entire cane-growing areas of Java in the course of a few years.

This variety was introduced to Queensland, by the Bureau of Sugar Experiment Stations, in 1928. Our pathologist soon made use of the valuable property which it possessed of high resistance to gumming disease, while subsequent yield trials established its general suitability for Southern Queensland conditions, where it exhibits drought-resistance, good sugar content, and excellent ratooning qualities over a wide range of soil types.

Although this example illustrates the benefits of following a carefully conceived breeding plan, it must, however, be recorded that whereas a wild cane species, such as Glagah, confers on its progeny resistance to certain diseases, this is by no means true for all cane maladies. Thus the majority of hybrids of this series are much more susceptible to Fiji, downy mildew, and top rot (red stripe) diseases than the standard noble canes. Extensive searches have therefore been made for wild types possessing the characters which Glagah lacks, and at the present time quite a volume of valuable material is receiving attention at the hands of the cane-breeder. Only by systematic study, in conjunction with the researches and trials of the pathologist, is it possible to determine along which lines success is likely to be achieved. The need for superior canes of the desired types is just as acute as ever, and only by systematic planning combined with sustained experimentation, will the consummation of these desires be possible.

TECHNIQUE OF CANE BREEDING.

The methods employed in raising cane seedlings vary considerably in detail, depending on local conditions. The first essential is a selected area in which the parent canes may be relied upon to flower or "arrow" freely, and where a good supply of pollen is produced by the canes which will be required to function as male parents. In Queensland, such a combination of circumstances is by no means common. Perhaps the most suitable area is a localised centre in the Freshwater district, north of Cairns. The "variety garden" of the Bureau is located in this area. This collection of canes embraces all those varieties, both local and imported, which might be expected to contribute valuable characters to their progeny. Unfortunately there exists no method of pre-determining the possibilities of a selected parental combination, and the tedious method of "trial and error" must be employed. While certain valuable parents produce promising seedlings, others give progeny which are consistently inferior, and are promptly discarded.

* The initials P.O.J. signify Proefstation Oost Java (or East Java Experiment Station), where it was bred.

In the selection of canes which are to function as female parents, only those varieties which do not produce "active" pollen, or which are self-sterile, can be considered. Those which produce a profusion of pollen grains are employed as male parents. The object of the breeding process is to produce cane seed, which carries the characters of both the female cell and the male pollen cell, with which it is fused. The character of the new individual seedling, as represented by the germ of the tiny seed, is therefore the resultant of the characters contributed by its parents. As the number of possible combinations of this nature is almost limitless, so the progeny of a given parental combination will differ widely amongst themselves in almost all particulars.

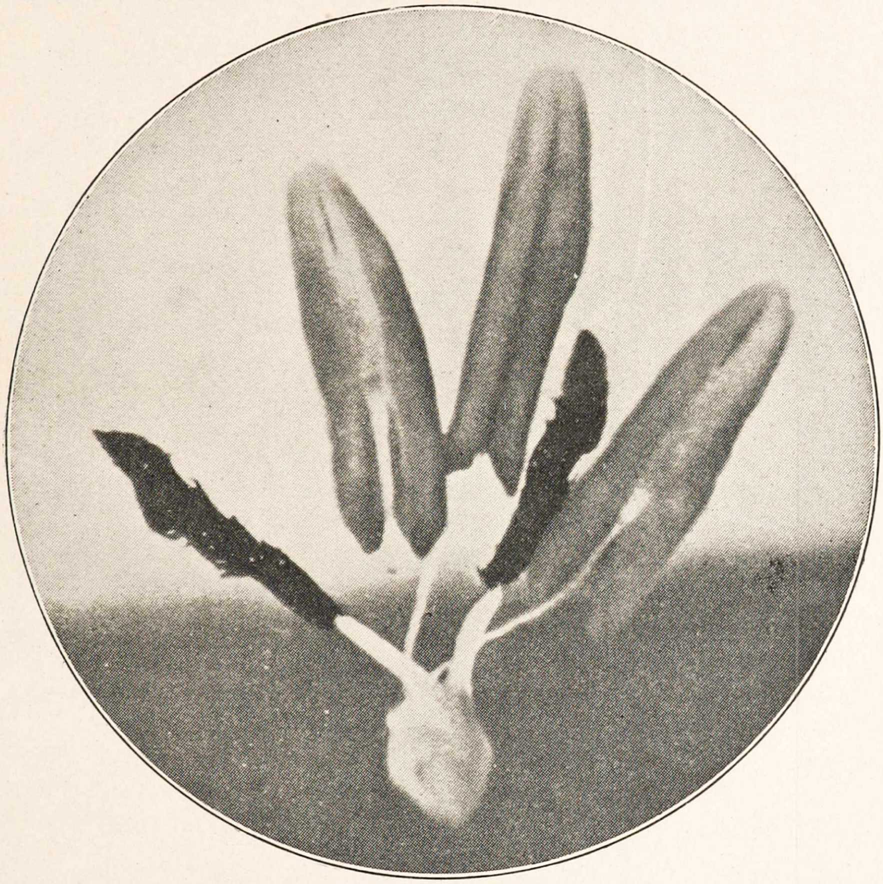


FIG. 102.—Photograph of a single cane "flower," greatly enlarged. Pollen is produced by the anthers (banana-shaped), while the stigmas (feather-like) are the female organs which function in the process of seed production.

The technique usually employed in the work is to surround the arrow or tassel of the female cane with arrows from the male parent. It was discovered in Hawaii that cut stalks of cane may be preserved by immersing the cut ends in a weak solution of sulphurous acid: the stalk may thus be kept "alive" for three or four weeks, and if it bears an arrow, the flowers will continue to open normally and allow the free production of pollen to continue. The pollen grains are shed chiefly in the early morning hours, and in order to assure a heavy cloud of pollen grains for the fertilization of the newly-opened female flowers, the cane breeder usually taps or shakes the male arrow at this period.

When all the tiny flowers of the female arrow have opened and died off, the male tassels are discarded, and the female arrow enclosed by an open-textured cloth bag, which allows the seed to ripen while eliminating the danger of loss through the action of the wind. In the course of

FIG. 103.—Illustrating the method whereby cross-pollination may be effected with cut stalks of cane. Here both male and female arrows are standing in a weak solution of sulphurous acid.

three or four weeks the ripening is complete. The seeds, which are considerably smaller than a pin's head, are light to dark brown in colour. They do not keep well, except by special treatment in cold storage, and

it is customary to plant them immediately to assure a high percentage of germinations. It is not usual to separate the seeds from the arrow, but to plant the entire "fuzz" stripped from the arrow in a shallow tray, or "flat," of specially prepared soil-compost mixture. As high

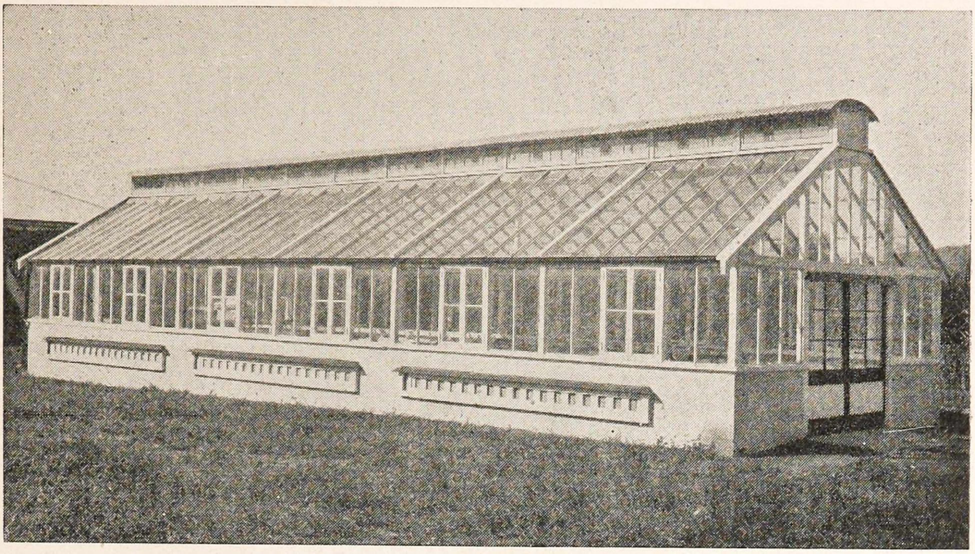


Fig. 104.—The Meringa glasshouse, where the seed is germinated and the young seedlings grown under favourable conditions of warmth and moisture.

temperatures are necessary for speedy germination and early seedling growth, the flats are usually placed in a glasshouse, while special attention is paid to the maintenance of a high atmospheric humidity. In two or three days the small green shoots may be seen, and possess the appearance of young grass seedlings. They are rather delicate at this stage, and demand constant attention to ensure the desired degree of heat and humidity which favours their development.

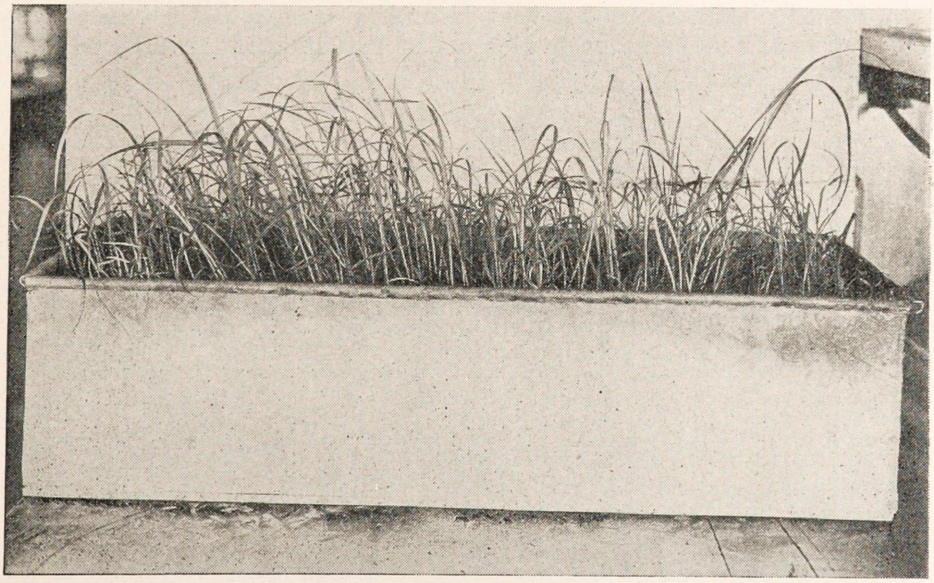


Fig. 105.—Illustrating a flat of young cane seedlings, ready to transplant to individual pots.

At the age of four to six weeks they are large enough to transplant to small galvanised iron pots filled with loam. They are placed in the full sunlight, with protection from winds, and water containing nutrients is added to speed up their growth. By September, they are usually sufficiently well advanced to allow of their being transferred to the field,

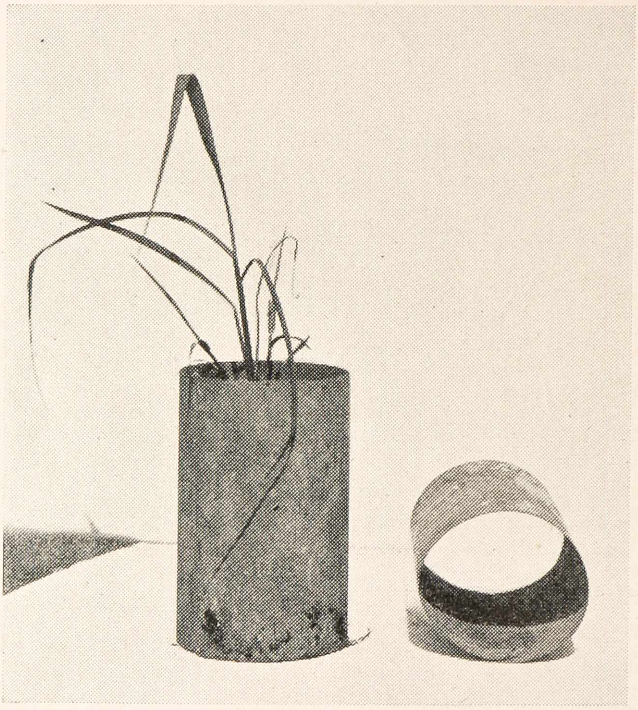


FIG. 106.—Showing the nature of the seedling pots employed. Note that the young seedling is already stooling.

where they are placed, at 3-foot intervals, in the usual planting furrows. By the judicious employment of fertilizer and irrigation water they are again forced ahead, so that a year later they are developed into fully-grown stools of cane, and a selection of the best individuals may be made.

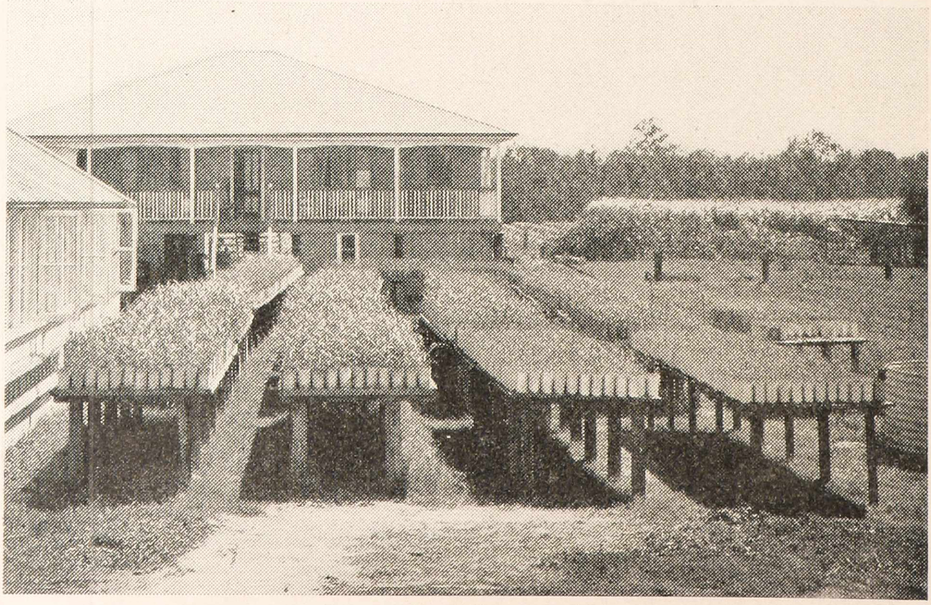


FIG. 107.—Potted seedlings arranged on exposed benches at Meringa Station.

The extent to which the progeny from one cross may vary is exemplified by inspection of the mature canes. Fine upstanding stools with ten and 12 stalks are found alongside veritable runts, and all intermediate stages usually exist. In general not more than one seedling is selected from 100 original plantings: hence from 10,000 seedlings planted in the field, not more than 100 may survive the first selection. This selection is based essentially on gross characteristics; whilst selecting by virtue of favourable characters, sprawling habit, prominent eyes, and other unsatisfactory features are carefully looked for and guarded against.

FIG. 108.—Showing a field of young seedling canes being irrigated at Bundaberg Station.

Such seedlings as are selected are planted in short rows, interspaced with short rows of standard canes, to serve as a basis for comparison, and are then grown under normal field conditions. At maturity they are again examined, while those regarded as worthy of further trial are tested for sugar content and period of maturity. About 10 per cent. of the first selections may be planted out once more, on a somewhat larger scale, for the third year, during which period more careful attention is paid to germination and ratooning behaviour, and further maturity studies are carried out. At this stage they are also placed in disease resistance trials. After observational yield trials on the Experiment Station, those canes of decided promise are placed in carefully planned farm yield trials against suitable standard varieties of the area, under a range of soil types.

It is therefore evident that from the time a seedling is first produced by cross-pollination until the plant breeder is confident in recommending it for trial commercial plantings, a period of at least five or six years must elapse. Certain exceptions to this rule may be found, as was the case with P.O.J. 2878—the Java "Wonder Cane." This variety was selected as possessing outstanding promise in the first year of its

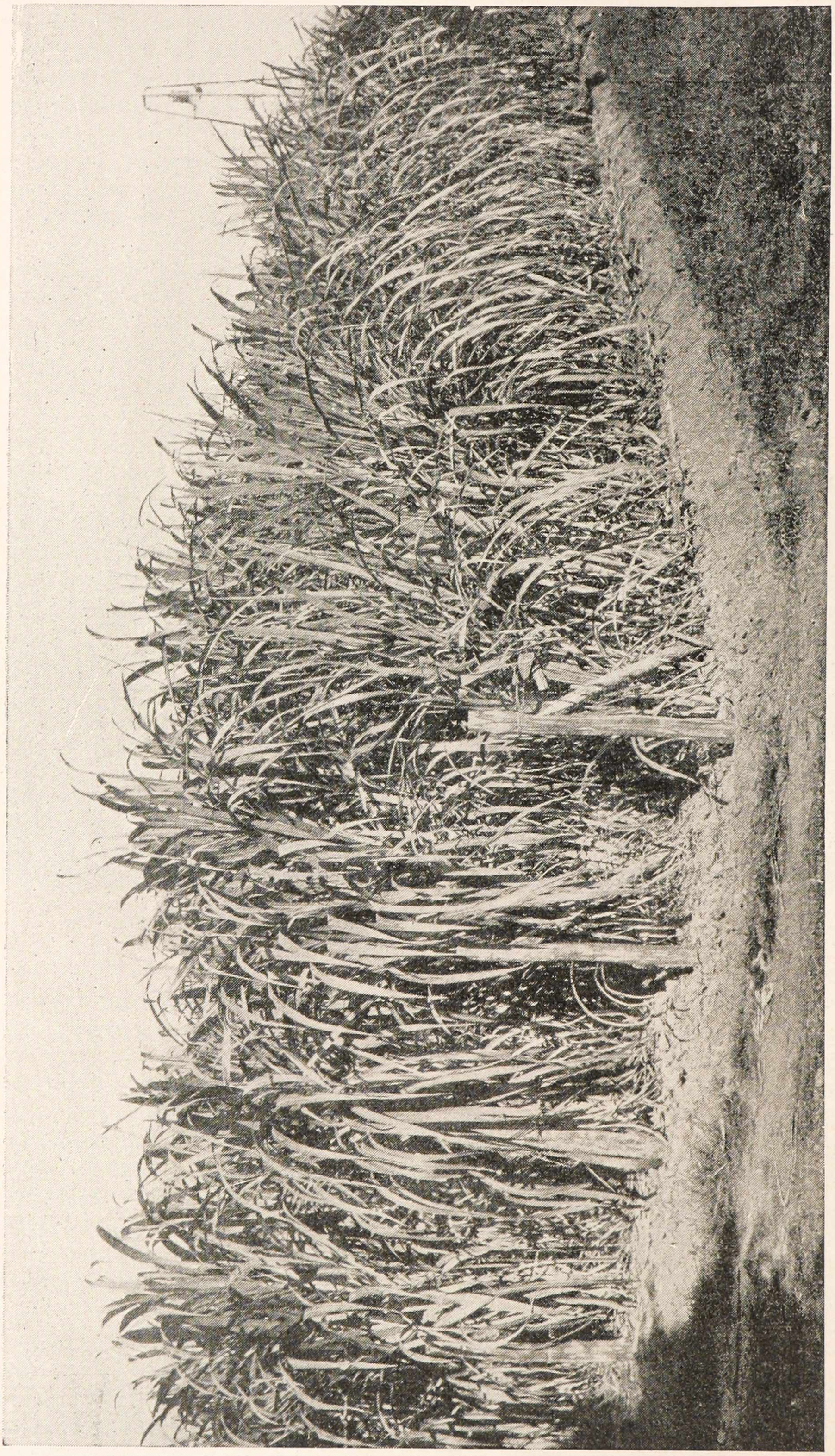


FIG. 109.—Illustrating the appearance of a field of seedling canes, a year after they were germinated from tiny seeds.

existence, and was rapidly propagated during the ensuing three or four years.

FIG. 110.—Two canes under field trial to determine their relative yield capacities.

IDENTIFICATION OF CANE VARIETIES.

The observant farmer who has "grown up in cane" usually has no difficulty in recognising one of the common cane varieties at a glance, if he has had any contact with it at all. To the inexperienced, the differentiation of similar varieties demands considerable care and study. On a cane-breeding station, where it is necessary to identify with certainty large numbers of canes, some scientific system of recognition becomes necessary. Workers in Java have shown us that the most valuable characteristic for this purpose is the arrangement of hair groups on the buds and leaves of the cane stalk. This method of description, for recording purposes, is employed almost uniformly, but it is not a method which the farmer can be expected to acquire readily, or employ.

Attempts have been made to prepare descriptions by which varieties may be readily identified by the grower, but these are never entirely satisfactory, due to the wide variations in gross characteristics of the same variety grown under different conditions.

In the list of more important varieties which follows, brief notes only are presented, in the hope that they afford a guide to the new grower, not in the identification of canes, but in the selection of the most suitable varieties for his purpose.

CANE VARIETIES GROWN IN QUEENSLAND.

Badila.

Introduced from New Guinea in 1896: serial number N.G. 15.

Growth Notes.—A cane which is widely grown on the better class soils of central and northern Queensland. Gives good germination, stools,

well, grows vigorously, and provides a good cover. It matures about mid-season, is rich in sugar, and holds its c.c.s. content very well; a strong ratooner.

Range.—Mossman to Mackay.

Reaction to Pests and Diseases.—Due to soft rind and low fibre, is very susceptible to beetle borer and rat damage: it is also damaged rather readily by grubs. It is susceptible to gumming, top rot, chlorotic streak, and mosaic disease, though it is moderately resistant to gum in North Queensland. It is resistant to leaf scald, Fiji, and downy mildew diseases.

B. 147.

Introduced from Barbados in 1898.

Growth Notes.—This variety is now grown on a comparatively small area of North Queensland, where it seems to do well on flooded country. Has a pronounced lodging habit, and often ratoons poorly when cut early.

Range.—North Queensland areas.

Resistance to Pests and Diseases.—Highly resistant to gumming, leaf scald, and top rot: these are its major virtues. Susceptible to mosaic and downy mildew. Moderately resistant to borer attack.

Fig. 111.—Mill trucks loaded with Badila cane, which is still the leading variety in North Queensland.

B. 208.

Introduced from Barbados, West Indies, in 1898.

Growth Notes.—This variety does best on the better class of loamy soil. It germinates well, gives a good stool and cover, and shows fair to good growth vigour. It matures rather early in the season, and gives a very high c.c.s. It is also a fairly good ratooner.

Range.—Formerly Mackay and north, but is rapidly passing out of cultivation due to disease.

Disease Reaction.—Susceptible to gumming, mosaic, Fiji, and downy mildew disease; resistant to leaf scald and top rot.

Clark's Seedling. (Colour sports also known as Benbow, P.Q. 1, and Gaspari.)

Bred by the C.S.R. Co. at Hambledon, North Queensland: serial number H.Q. 426.

Growth Notes.—This variety is grown over a wide range of soil types in central and northern Queensland. It gives excellent germination, fair to good stooling, and rapid early growth. It provides good cover. A major virtue is its early maturity, and it is often harvested when 10 months old. Sugar content very fair to good. It ratoons moderately well.

Range.—Mossman to Mackay.

Reaction to Pests and Diseases.—It is susceptible to beetle borer and grub attack, and is also damaged by rats. While resistant to top rot and downy mildew diseases, it is susceptible to gumming, leaf scald, mosaic, Fiji, and chlorotic streak diseases.

Co. 290.

Bred at Coimbatore, S. India.

Growth Notes.—Vigorous growth over a wide range of soil types, though on wet soils it becomes rank and gives low C.C.S. A good striker, strong stooler, and gives fair sugar content, but is late maturing. It is an excellent ratooning cane. Does not standover well.

Range.—Mackay to Beenleigh.

Reaction to Pests and Diseases.—This variety should be resistant to grub attack: it is resistant to gumming, leaf scald, and Fiji disease, and moderately resistant to downy mildew.

D. 1135.

Introduced from Demerara (British Guiana), in 1895; also known as "Fairymead" or "Bundaberg."

Growth Notes.—This variety is suited to the poorer class of soil; it gives fair to good germination and stooling, but does not cover well. It shows moderate vigour and growth; its sugar content is only poor to fair, with medium-late maturity. It ratoons satisfactorily.

Range.—Formerly this cane was planted in all cane areas of the State, but has now been replaced very largely by other varieties.

Reaction to Pests and Diseases.—It is resistant to the attack of the beetle borer, and moderately so to grubs; towards leaf scald it is resistant, is moderately resistant to downy mildew, but it susceptible to gumming, mosaic, and Fiji diseases.

E.K. 28.

Bred in Java: introduced by the Bureau of Sugar Experiment Stations in 1916.

Growth Notes.—This variety is chiefly grown on the medium and heavier lands of the Mackay and Burdekin areas. It gives a satisfactory germination and stooling, and is of good growth vigour, covering

the interspace reasonably well. It is rather a late maturing variety, and gives a good C.C.S. It is a fair ratooner.

Range.—Burdekin to Mackay.

Reaction to Pests and Diseases.—It is susceptible to grub attack, and also to gumming, leaf scald, mosaic, and Fiji diseases; it is moderately resistant to downy mildew.

Fig. 112.—Cutters harvesting an excellent crop of E.K. 28, a seedling variety produced in Java.

H.Q. 285.

Bred by the C.S.R. Co. at Hambledon, North Queensland; also known as "Milton" and "Early Maturer."

Growth Notes.—Suited by moister conditions and low lying fields. Fair germination, stooling, growth vigour and covering qualities. Should be planted at narrower than standard interspace. Early maturing and fair to good C.C.S. Fair ratooner.

Range.—Mackay to Beenleigh, but now grown on a very restricted scale. Chief virtue is early maturity.

Reaction to Pests and Diseases.—Susceptible to grub attack, and to gumming and mosaic diseases: moderately resistant to Fiji.

H.Q. 409.

Bred by the C.S.R. Co. at Hambledon, North Queensland.

Growth Notes.—It makes good growth on the poorer clayey lands of North Queensland, notably under wet conditions. It gives fair to good germination, and good stooling, moderately good cover and growth vigour; matures mid-season and is of medium sugar content. Ratooning poor when harvested early in the season; later it is good.

Range.—Mossman to Ingham.

Reaction to Pests and Diseases.—As it is not grown extensively in areas seriously subject to grub and borer attack, its resistance is not known. It is resistant to top rot, and moderately resistant to gumming, leaf scald and downy mildew. Was grown extensively in the Herbert River district when that area became infected with gumming disease.

Korpi.

Introduced from New Guinea in 1914; serial number 14 N.G. 124.

Growth Notes.—This variety grows well on the better class of soil, and demands favourable growing conditions. Germination, stooling, and covering qualities are good, and it shows fair growth vigour. It is a rather early maturer, and gives high C.C.S. Ratooning qualities only fair.

Growth Range.—Northern districts and on irrigated farms of southern Queensland.

Reaction to Pests and Diseases.—It is not grown in grub or borer infested areas: it is resistant to gumming disease, moderately resistant to Fiji, and moderately susceptible to leaf scald and mosaic.

Mahona.

Introduced from New Guinea in 1896; serial number N.G. 22.

Growth Notes.—Rather a light cropping variety with sparse foliage: owes its value to its frost resistance and good C.C.S. content when cut early in the season. Also ratoons well when harvested at this time.

Range.—Southern Queensland.

Reaction to Pests and Diseases.—Fairly resistant to Fiji and mosaic diseases, very highly susceptible to gumming and leaf scald. Grown to a limited extent only in the southern areas where pests are not a serious problem.

M. 1900.

Introduced from Mauritius; also known as "1900 Seedling."

Growth Notes.—This variety is planted on the medium to good lands of central and southern Queensland. It gives a fair to good strike, but only moderate stooling, with fair cover and growth vigour. It matures mid- to late season, and gives a high sugar content. It ratoons fairly well.

Growth Range.—Mackay to Maryborough.

Reaction to Pests and Diseases.—It is susceptible to grub attack, and also to leaf scald, gumming, Fiji, top rot and red rot diseases. It was formerly grown extensively in southern Queensland, but has been almost completely eliminated in those parts by gumming and Fiji diseases.

Oramboo.

Introduced from New Guinea in 1914; serial number 14 N.G. 190.

Growth Notes.—This variety grows well on the better class of soil, and requires rather moist conditions. Germination, stooling, and covering qualities are good, with fair growth vigour. Rather early maturing, with high C.C.S. Ratooning qualities only fair.

Growth Range.—Planted on a small scale from northern to southern Queensland.

Resistance to Pests and Diseases.—Highly resistant to gumming, fairly resistant to Fiji, mosaic, downy mildew, and leaf scald. Not grown extensively to date where borers and grubs are bad.

P.O.J. 213.

Also known as "Little P.O.J." Bred at the E. Java Sugar Experiment Station, Pasoeroean, and introduced into Queensland in 1922.

Growth Notes.—This thin variety grows well over a wide range of soil types, but shows a tendency to rank growth on wet soils. It gives a good germination, stools and grows vigorously, covers well, and is drought resistant. It has a fair C.C.S. content at maturity, and matures about mid-season.

Range.—Mackay to Beenleigh.

Reaction to Pests and Diseases.—Though susceptible to mosaic and downy mildew diseases, it is resistant to gumming, leaf scald, top rot, and Fiji. It is also resistant to borer and grub attack.

P.O.J. 234.

Bred at the E. Java Sugar Experiment Station, Pasoeroean.

Growth Notes.—This variety is adapted to a wide range of soil types: tends to rank growth and low sugar content on wet soils. Good germination, fair stooling, rather poor cover due to erect growth habit, and fair growth vigour. It is early maturing, and gives a fair to good C.C.S. Also highly resistant to drought, and satisfactory ratooner.

Range.—Bundaberg to Beenleigh.

Reaction to Pests and Diseases.—Should be resistant to grub and borer attack, and is resistant to gumming, leaf scald, top rot, and Fiji diseases. Susceptible to mosaic.

P.O.J. 2714.

Bred at the E. Java Sugar Experiment Station, Pasoeroean. Introduced into Queensland in 1922.

Growth Notes.—This variety grows well over a wide range of soil types, including sandy loams. Germination, fair to good, though variable: stools and covers well, and possesses excellent growth vigour. It is rather late maturing, and gives fair to high C.C.S. It is a good ratooner.

Range.—Giru and Mackay Districts.

Reaction to Pests and Diseases.—Due to its hard stem and vigorous rooting system, it is resistant to the attack of borers and grubs. It is, however, susceptible to gumming, Fiji, top rot, and downy mildew diseases, though resistant to mosaic and moderately resistant to leaf scald. Its disease susceptibility is largely responsible for its restricted propagation.

P.O.J. 2725.

Bred at the E. Java Sugar Experiment Station, Pasoeroean. Introduced into Queensland in 1930.

Growth Notes.—This variety is noted for its vigorous growth, excellent stooling and ratooning qualities, and drought resistance. But it is a free and early arrower, and the stem tends to pithiness. Mid-season maturer, giving fair to good C.C.S.

Range.—Burdekin to Bundaberg.

Reaction to Pests and Diseases.—Resistant to grub and borer attack, and resistant to gumming, mosaic, leaf scald, top rot, and downy mildew diseases: susceptible to Fiji.

P.O.J. 2878.

Also known as Java "Wonder Cane." Bred at the E. Java Sugar Experiment Station, Pasoeroean, and introduced into Queensland in 1928.

Growth Notes.—This variety is adapted to a wide range of soil types. It gives fair to good, though variable, germination, but is a vigorous grower, good stooler, and covers well. It is an excellent stand-over type in Southern Queensland, and is drought resistant. As a late maturer, it gives good C.C.S., and ratoons vigorously. Tendency to pithiness and arrowing in North Queensland.

Range.—All districts of the State—particularly favoured in the southern areas.

Reaction to Pests and Diseases.—It is resistant to borer and grub attack, and to gumming, mosaic, and leaf scald diseases: but it is susceptible to top rot, Fiji, and downy mildew.

Pompey.

Bred at Rarawai, Fiji Islands, by the C.S.R. Company; serial number, 7 R. 428.

Growth Notes.—Is suited to the poorer class of North Queensland soils. Shows fair to good germination, fair stooling and cover, and vigorous growth. It is, however, low in sugar content, which is a serious objection to its propagation. It ratoons satisfactorily.

Range.—Mossman to Tully.

Reaction to Pests and Diseases.—Towards pest attack it shows no outstanding characteristics of resistance or susceptibility: it is resistant to top rot disease, but is susceptible to gumming: it is moderately resistant to leaf scald, mosaic, and downy mildew.

Q. 2.

Bred at the South Johnstone Sugar Experiment Station, North Queensland, in 1931.

Growth Notes.—This variety gives fair to good strike, and stools well; thin sticks which are very free trashing; cover only fair, and allows growth of winter weeds. Mid-season maturity, giving medium C.C.S. Does not ratoon well when cut early in the season. Chief virtues are—resistance to damage by flood, grubs and borers. Does best on moist alluvial lands.

Range.—Mossman to Tully.

Reaction to Pests and Diseases.—Highly resistant to top rot, fairly resistant to leaf scald and gumming; somewhat susceptible to downy mildew and care should be exercised. Highly resistant to borer injury, and so far seems to withstand grub attack fairly well.

Q. 813.

Propagated by the Queensland Acclimatisation Society in 1906.

Growth Notes.—Good germination and quick striker, moderate stooling and growth vigour. Though rich in sugar, it is usually a light yielder, and is decidedly a weak ratooning cane. Its major virtue is disease resistance.

Range.—Grown sparsely in all areas, but chiefly in the Mackay District.

Reaction to Pests and Diseases.—Highly resistant to gumming, leaf scald, top rot and red rot, and fairly resistant to Fiji, downy mildew and mosaic. Not grown extensively in borer areas, and its weak rooting system suggests that it would not withstand grub attack.

Fig. 113.—A good crop of Q. 2, bred in North Queensland. Note the characteristic free-trashing habit of the variety.

S.J. 2.

Bred at the South Johnstone Sugar Experiment Station, North Queensland, in 1922.

Growth Notes.—This variety requires good growing conditions for heavy crops, and is grown chiefly by virtue of its very high sugar content (up to 19 C.C.S.). Germination fair to good, fair stooling and cover, and moderate growth vigour. Early to mid-season maturity. Ratooning fair.

Range.—Burdekin and Mackay areas.

Reaction to Pests and Diseases.—Susceptible to grub and borer attack, and to gumming and leaf scald diseases: moderately susceptible to mosaic, but downy mildew resistance not known.

S.J. 4.

Bred at the South Johnstone Sugar Experiment Station, North Queensland, in 1922.

Growth Notes.—This variety is suited to the medium and poorer class soils of Northern Queensland. It gives an excellent germination and stooling, has vigorous growth and rooting qualities, and covers well. It is a late maturing variety, giving moderate C.C.S. Its ratooning qualities are good.

Range.—Mossman to Mackay.

Reaction to Pests and Diseases.—S.J. 4 withstands grub and borer attack rather better than other major varieties in North Queensland. It is, however, highly susceptible to gumming disease: also susceptible to leaf scald and chlorotic streak, though moderately resistant to downy mildew. Its sensitivity to leaf scald, which kills affected stools, enables the variety to survive in a relatively scald-free condition.

S.J. 7.

Bred at the South Johnstone Experiment Station in 1922.

Growth Notes.—Fair striker, good stooler, and rapid grower. Mid-season maturity, and good C.C.S. Ratoons satisfactorily. Although it gave high yields in trials in North Queensland, its susceptibility to leaf scald rules it out in those parts.

Range.—Lower Burdekin area.

Reaction to Pests and Diseases.—Fair resistance to downy mildew in the Burdekin district, highly susceptible to gumming and leaf scald, and rather susceptible to top rot. Not grown in areas where pests are troublesome, but should be similar to Badila in its reactions.

Chapter XIII.—DISEASES OF SUGAR-CANE.

INTRODUCTION.

Queensland is particularly unfortunate inasmuch as, although none of the important diseases of sugar-cane is indigenous to the country, almost every disease of great economic importance has been introduced, and is now present within the State. The reasons for this misfortune are two-fold:—Firstly, sugar-cane has been grown over the wide climatic range from Port Macquarie, in New South Wales, to Cooktown, in North Queensland and, consequently, the continuous search for new and better varieties has involved importations from practically every cane-producing country in the world. Secondly, plant pathology is but a very young science and most, if not all, of these diseases had been introduced into Queensland before agricultural science had developed to the stage where suitable precautions could have been taken to prevent their entry. The control of sugar-cane diseases in Queensland is, consequently, a much bigger problem than in other countries, and the problem is further complicated by the fact that the industry is conducted under the small farm system, which greatly limits the capital expenditure available for disease control purposes.

Economic losses as the result of the ravages of plant diseases may be avoided or reduced by the following methods:—1, Quarantine; 2, Plant selection; 3, Improved or special agricultural methods; and 4, The use of resistant varieties. Under the particular conditions ruling in Queensland, which are outlined above, it has been considered necessary to place particular emphasis on the production of disease-resistant varieties of cane, and this phase of disease control is being extensively developed in this State. These four chief methods of disease control will now be considered briefly in turn.

1. Quarantine.

Under the provisions of the Sugar Experiment Stations Acts, the Government is enabled to proclaim quarantines; these are of two types, viz., foreign and local quarantines, and in each case the object is to prevent the introduction of a disease into an area where it has not previously existed. The foreign quarantine measures prohibit the haphazard introduction of foreign varieties from abroad, and in the case of Queensland, the sole right of the importation of foreign cane varieties is vested in the Bureau of Sugar Experiment Stations. Varieties which are imported by the Bureau are, in the first place, obtained only from countries where competent pathologists are resident, and the disease situation is such that there is little risk of introducing a new disease. Upon receipt of the cane in Queensland it is carefully disinfected and is then grown for a period of at least one year, under the constant supervision of the pathologists. Should the cane exhibit any symptoms of disease during this period it is discarded and destroyed.* Local quarantines, on the other hand, are established to prevent the further spread of diseases

* Diseases may exist in "strains" of varying severity. For example, one of the strains of mosaic in Louisiana may be more destructive to standard varieties than the strain found in Queensland. Therefore it is equally necessary to guard against the introduction of possible new strains of diseases which are already present in this State.

which have already gained entry into the country. Fortunately, the chief cane diseases are not all generally distributed throughout the State. For example, leaf-scald disease is not present south of Mackay, while gumming disease (except for two small outbreaks) is not found in the Northern districts. Similarly, Fiji disease is confined to the southern end of the cane belt, while dwarf disease is restricted to a small area in the Mackay district.

Since diseases are always spread from country to country, or district to district, by the transfer of diseased planting material, it is very important that plants should not be taken from a district where a particular disease is present, to one where this disease is not present. Very serious consequences to the sugar industry might follow, for example, if some thoughtless person took some Fiji diseased cane from the Bundaberg district and planted it in North Queensland. Naturally, a person would not knowingly plant diseased cane, but it so happens that the symptoms of most diseases may be masked for fairly long periods of time and cane which is apparently quite healthy may be diseased. In order to reduce the likelihood of the industry in any particular district being jeopardised by the introduction of a new disease in planting material brought in from another district, the State has been divided into nine sugar-cane quarantine districts. The removal of sugar-cane plants from any one of these districts to any other district is prohibited under the Act unless a permit to do so has been issued by the Bureau of Sugar Experiment Stations. The boundaries of these sugar-cane quarantine districts correspond approximately to lines drawn east and west through the following points:—Buchan's Point, Cardwell, Townsville, Bowen, Alligator Creek (to the south of Mackay), Rockhampton, Howard, Hook Point (on the southern end of Great Sandy Island), Brisbane, and the New South Wales border (*see* Fig. 114). In addition, the introduction of cane from New South Wales is absolutely prohibited unless a certificate as to freedom from disease has been issued by the Bureau.

2. Plant Selection.

Plant selection is an important method of disease control which is applied when a particular disease is actually present in a locality and some or all of the varieties grown are susceptible to that disease. It aims at prevention, or what we might term "escaping" a disease by the careful selection of healthy planting material. The extent to which this method may be successfully employed depends on the type of disease, and the manner in which it is spread, and local conditions. It is very evident that before plant selection can be practised to any degree, the farmer must make himself well acquainted with the symptoms of any diseases against which he wishes to select and, furthermore, he must be able to recognise them in their early stages. In this article are included descriptions and illustrations of the symptoms of the nine more important diseases present in Queensland, and these should enable farmers to recognise the diseases in question. If desired, further information may at all times be obtained from illustrated pamphlets issued by the Bureau, or from the field officers who are stationed in various centres.

The method of plant selection to be employed will again depend upon the characteristics of the particular disease under consideration. When the symptoms are permanent and uniform, as in the case of mosaic and dwarf diseases, healthy plants may often be satisfactorily selected

in a field in which the disease occurs. It should be remembered, of course, that the symptoms of both these diseases may remain masked for periods of time, and so the plant selection should be followed up by careful inspections of the young plants and the up-rooting of any diseased stools.

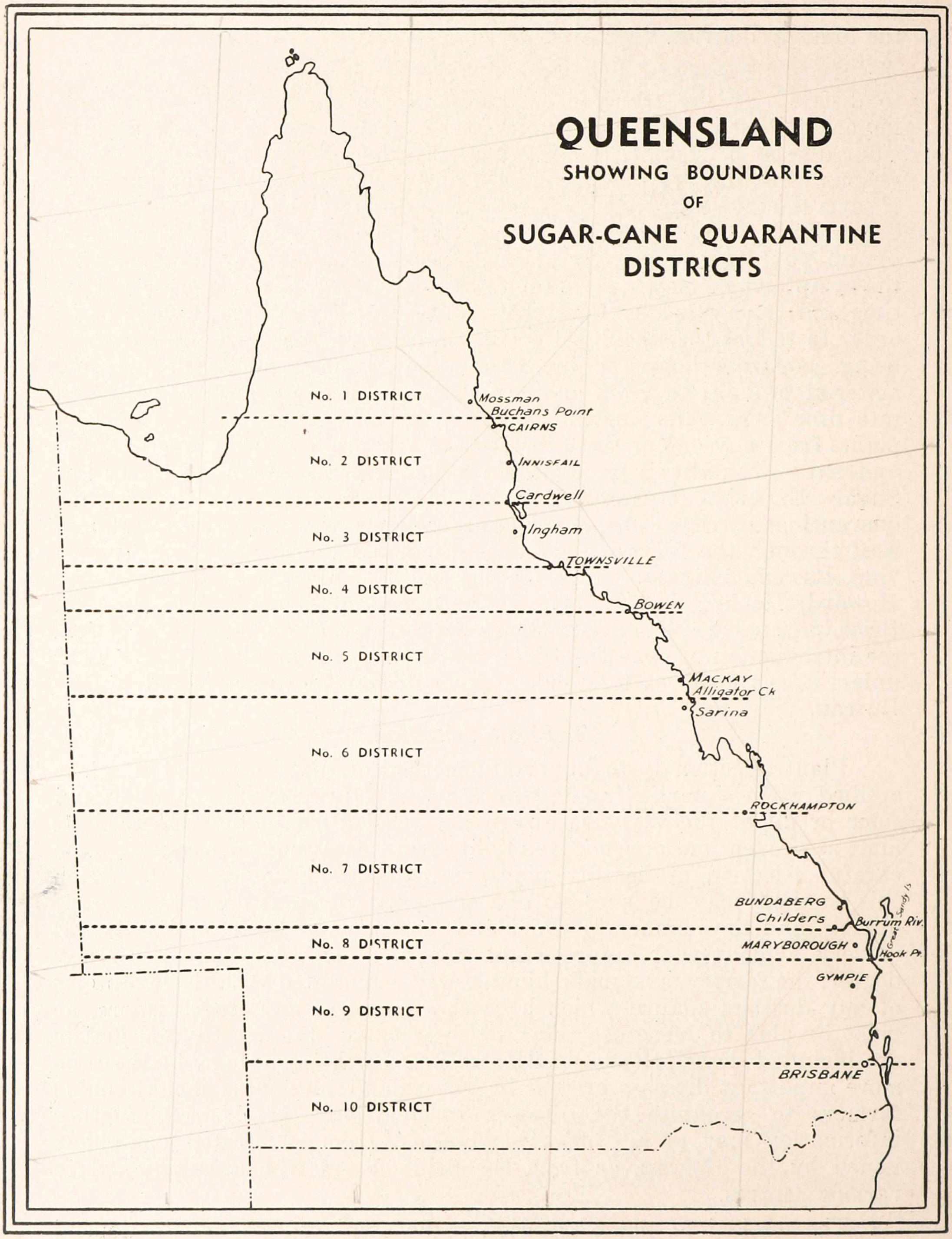


FIG. 114.—Map of Queensland, showing boundaries of Sugar-cane Quarantine Districts. Sugar-cane may not be moved from one district to another without a written permit from an inspector under the Sugar Experiment Stations Act. An exception is made in the case of cane consigned to a sugar-mill for milling purposes.

In contrast to these two diseases, the symptoms of gumming, leaf-scald, and chlorotic streak disease appear and disappear according to weather conditions, and other causes, particularly in the early stages of the disease. As a result it is impossible to select plants in a diseased field on the stool basis, and once any diseased plants have been observed the *whole field* should be discarded as a source of plants. Indeed, in the case of gumming and leaf-scald diseases, at least, no plants of susceptible varieties should be taken from within a quarter of a mile of a diseased field. Of a somewhat different type is downy mildew; here the symptoms are constant, but infection takes place through the eyes on the standing stalk of cane, and hence the stalk may be diseased although from the exterior the cane appears quite healthy. In this case plants of susceptible varieties should not be taken from within, say, a furlong of the nearest diseased plant.

It follows then that in selecting plants of susceptible varieties when gumming, leaf-scald, and downy mildew are present, careful inspections must be made not only of the field from which it is proposed to cut plants but also of the surrounding fields. At the other end of the scale are red rot and red stripe (top rot) diseases. In both instances the organisms or ''microbes'' which cause the disease are widely scattered and can live for some time in soil and trash. They are always present, ready to attack the cane as soon as conditions are favourable, and so very little is to be gained by plant selection as far as these two diseases are concerned.

3. Improved or Special Agricultural Methods.

This section deals with those cases where the disease is actually present in fields of susceptible varieties, and so it becomes necessary to take steps to reduce losses as much as possible. Although there are some exceptions to the rule, it may be generally accepted that any practice which will increase the vigour and vitality of the plant will also enable it to withstand to a greater extent the attacks of diseases. A number of organisms which cause plant diseases are but weak parasites and can only attack the plant after it has received a setback as a result of some unfavourable climatic condition, poor cultivation, or lack of fertilizer. Consequently, care should be taken to see that the cultural and fertilizer practices are the best available for the particular soil type.

Drainage is a particularly important factor influencing the severity of a number of diseases and should receive strict attention; on the other hand, a poor moisture-holding capacity of the soil is equally undesirable and should be improved by the conservation of the organic matter of the soil.

Cleanliness of the fields may be a very important consideration for two reasons:—(*a*) Certain weeds contract some of the same diseases as does sugar-cane and so they may act as sources of infection in the cane field, thus destroying any benefits of plant selection; (*b*) a disease may be transmitted from diseased to healthy cane by an insect which only feeds on cane by accident, and would not breed on it, but which thrives on various weeds and grasses. Both of these conditions operate in the case of mosaic disease, for example, and thorough cultivation for weed destruction is strongly advocated as a general disease control measure.

The time of planting or time of harvesting may have a great effect upon the severity of disease attack. With some diseases, such as mosaic

and red stripe (top rot), susceptible varieties become more resistant with age, and so every effort should be made to get the cane as far advanced as possible before the period of the year when the disease in question becomes prevalent. In the two cases which we have mentioned, a big improvement may be effected by planting in the autumn instead of in the spring. On the other hand, red rot is an example of a disease which mainly attacks over-ripe cane and it may be controlled by carefully watching the maturity of the cane and harvesting at the proper time. The losses from diseases which cause death of the mature cane may be reduced by early harvesting of the crop, and fields which are badly infected with gumming or leaf-scald diseases should be cut early.

4. Resistant Varieties.

It is a well-known and frequently observed fact that different varieties of sugar-cane differ markedly in their resistance or susceptibility to any particular disease; while the variety 1900 Seedling is badly affected by gumming disease, for example, the variety P.O.J. 2878 is very highly resistant to this disease and quite unaffected by its presence. It is only natural that full advantage should be taken of the existence of these resistant varieties since, by growing them, the sugar planter may completely eliminate losses from the diseases in question without being involved in the trouble and expense of plant selection or the adoption of any special agricultural methods. Control of diseases by the use of resistant varieties is permanent and automatic in its operation, and constitutes the ideal method and, in some cases, the only method. Against this is the fact that the search for resistant varieties is usually slow, tedious work, while there is also the fact that many excellent high-yielding varieties of high sugar content must be discarded because their standard of resistance is not sufficiently high.

It has been stated above that the special conditions under which the Queensland sugar industry is conducted require that the use of resistant varieties shall play a big part in the control of diseases in this State. Consequently, no variety is now released for propagation unless it has been proved to be resistant to the chief disease, or diseases, of the district in which it is to be grown. All new varieties, therefore, are planted out in disease-resistance trials, where they are inoculated with the various diseases, and the effect on these varieties is then compared with that on the old standard varieties whose field performance is well known. Should the new cane not prove sufficiently resistant it is discarded immediately, but if it is satisfactory from the disease point of view, it is then planted out in further trials to determine whether it is satisfactory in respect to yield, sugar content, time of maturity, &c.

In the continuous search for new and better varieties those of promise are imported from abroad, and in the last dozen years in the neighbourhood of 400 varieties have been imported into Australia. In addition the Bureau conducts an extensive seedling-raising programme and some 20,000 to 25,000 new varieties are raised and tested each year at the three Experiment Stations.

It is rarely found, of course, that any variety is resistant to all the major diseases listed above and the Bureau must necessarily release for planting many varieties which are susceptible to some of these diseases, which, however, are of secondary importance in the particular district. Consequently, it is desirable that the canegrower should know which of

these diseases is likely to attack each variety so that he may know what precautionary measures to take. Full information regarding the known disease resistance of any approved variety may be obtained from the Bureau.

Approved Varieties.

Nothing is more favourable to the perpetuation and spread of diseases than the growing of collections of miscellaneous varieties or small patches of susceptible varieties. In order to eliminate such sources of infection there are now published in the *Government Gazette* each year lists of varieties which are approved for planting in each mill district, and all other varieties are automatically disapproved and must not be planted. Indeed, heavy penalties are prescribed in the Sugar Experiment Stations Acts for planting non-approved varieties for milling, use as fodder, or for any other purpose.

DISEASE DESCRIPTIONS.

Descriptions and illustrations of the more important sugar-cane diseases of Queensland are appended. There are numerous other diseases of minor consequence, but space does not permit of their treatment here, nor do they merit much attention, except insofar as they might be confused with the major diseases. The relative importance of these diseases naturally varies greatly from district to district, the chief disease of one district possibly being of no moment in another.

Gumming.

Gumming disease must be regarded as a most serious cane disease in Queensland, and during the last fifteen years has been responsible for very great losses in the southern district. As a result of extensive resistance trials, however, there are now available a number of suitable highly-resistant varieties, the cultivation of which has eliminated gumming disease as an economic factor. At the present time the disease is still found in the Bundaberg-Childers and Moreton districts and on a few farms in the Bauple, Maryborough, and Ingham districts; a trace of the disease survives in the Mackay area, but it has not been much observed in the last few years. A few years ago a fresh outbreak occurred in the Gordonvale district near Cairns, but is now virtually under control.

In its early stages, gumming is a leaf disease; in resistant varieties it does not develop beyond this stage, but in susceptible varieties it passes down into the stem as soon as a check in growth occurs. The most convenient symptom for identifying the disease in the field is the presence of characteristic streaks upon the leaves. These streaks are yellowish in colour, but soon become dotted with a number of small reddish blotches (*see* Plate I.). They may be up to a $\frac{1}{4}$ inch wide, although usually about $\frac{1}{8}$ inch, and may arise in any portion of the leaf blade, but the majority arise towards the tip of the leaf; the length varies from a couple of inches to practically that of the leaf. Streaks follow the course of the large veins of the leaf and, as a result, they run out in straight, fairly even lines, at a slight angle to the midrib. As they become older dead patches arise in the streaks and gradually extend throughout most of the length, the streaks at the same time becoming broader and losing something of their regularity of outline (*see* Plate I.). These streaks are best found during the wet season and may disappear almost entirely during long spells of dry weather.

Plate I.

GUMMING DISEASE.—Leaf symptoms are the earliest symptoms observed; they consist of yellow to orange coloured streaks, flecked with numerous reddish dots, later developing ash-coloured dead areas. Streaks are straight and fairly regular in outline.

In susceptible varieties the disease later passes down into the stalk; in many cases there may be only a faint streak down the leaf sheath, but in others there are well marked broad whitish or dark-red streaks passing down into the heart of the cane. As the disease progresses the stalks, when cut open, show a pronounced reddening of the fibres, especially at the nodes, and later a yellowish-brown sticky "gum" or slime may be observed to ooze from the freshly-cut surface (*see* Fig. 115). This gum will usually ooze quite freely late in the season, but the oozing is assisted by placing a freshly-cut piece of cane in a closed can for a few minutes. Oozing of gum is the outstanding characteristic of the disease and is the one best known to farmers; it should be remembered, however, that it is a fairly late stage and that the earlier leaf streak stage is the more suitable for detecting the presence of the disease. In later stages still, the disease attacks the growing points of a percentage of the stalks, causing their death; this usually occurs from June onwards.

Gumming disease is caused by bacteria and the "gum" which oozes from the freshly-cut stems consists chiefly of myriads of these little organisms. The disease may be spread from sett to sett when cutting plants, some of the bacteria from a diseased sett being carried to a healthy sett on the cane knife. The chief method of spread, however, is from leaf to leaf during wet, windy weather; the spines on the margins of the leaves cause scratches on the surfaces of adjoining leaves and the bacteria swim out through these wounds on to the surface of the leaf. Some are then splashed on to a healthy leaf, swim in through similar wounds, and so infect the new plant. Gumming disease does not spread through the soil, but when planting after the ploughing out of an old diseased crop, care should be taken that there are no volunteer stools present as these will serve to infect the leaves of the new plant crop.

The effects of gumming disease are greatly accentuated by either bad drainage or poor moisture-holding capacity of the soil, and the correction of these faults will go a considerable way in the control of the disease. When planting susceptible varieties great care should be exercised in plant selection; the field from which it is proposed to cut plants and the surrounding fields should be inspected several times and the source of plants rejected if any signs of the disease are found. Since the disease usually does not pass down into the stalk until later in the season, autumn planting (using young cane) may assist in obtaining a clean stand. Since so many good resistant varieties are now available, however, this method of control is the sole method necessary, and a reference to Table I. will indicate the varieties most suitable.

Leaf-Scald.

Leaf-scald disease is widely distributed throughout the area north of Townsville and in scattered centres in the Proserpine district. At the present time its effects in the north are indirect rather than direct, since Badila, the standard variety, is reasonably resistant. The disease, however, is of great indirect economic importance, since in places it has almost eliminated the early maturing Clark's Seedling (H.Q. 426) and has prevented the growth of such highly promising seedlings as S.J. 7.

Leaf-scald exhibits two distinct phases, the acute and the chronic. In the acute phases the plant suddenly wilts and dies, as though it had been cut off from its root system; the symptoms of this phase, however,

Plate II.

LEAF-SCALD DISEASE.—In contrast to gumming disease (Plate I.) the leaf streaks typical of leaf-scald disease are white to cream in colour and very regular in outline in early stages. In later stages (centre and right-hand leaves) the streaks broaden and wither, giving the leaf a scalded appearance.

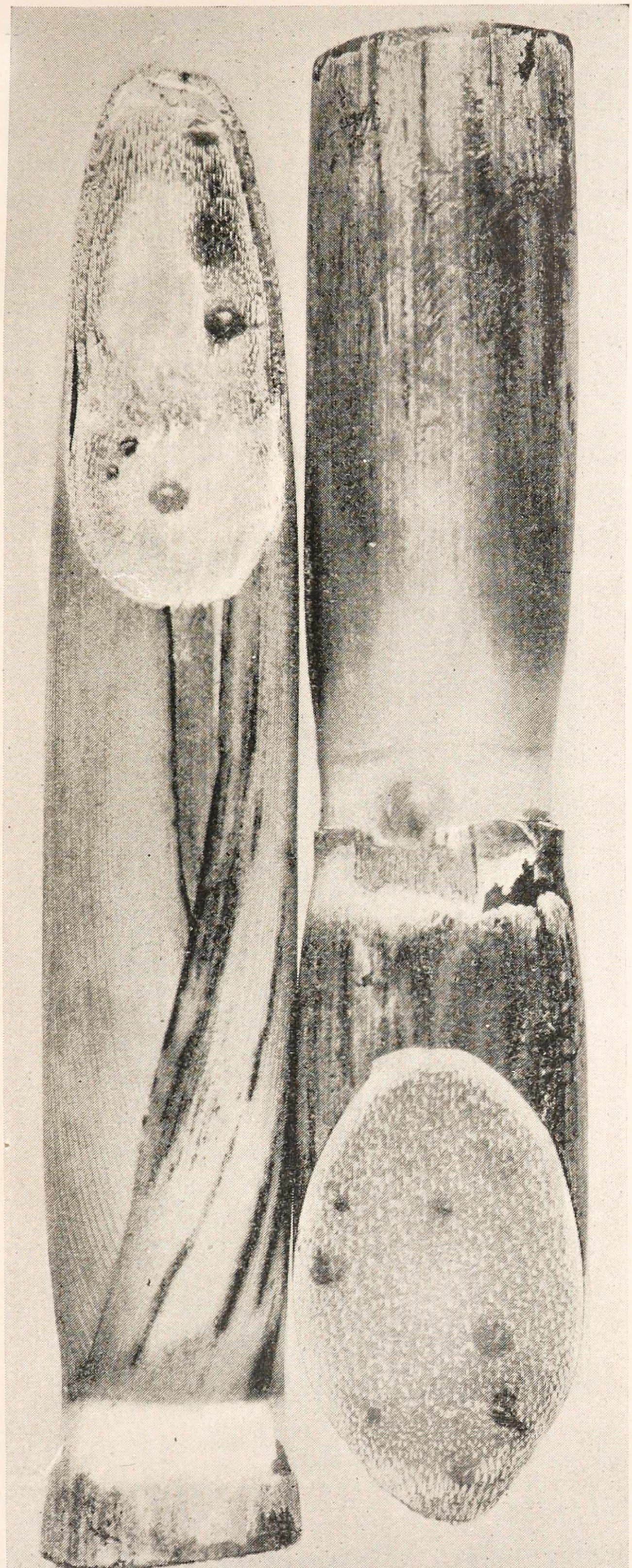
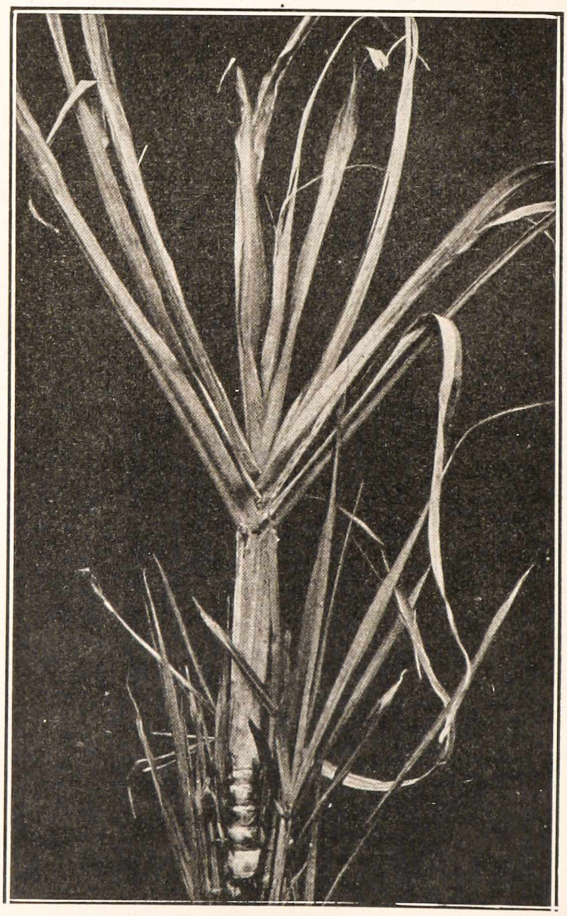


FIG 115.—Droplets of "gum" oozing from the freshly-cut surface of a stalk of cane diseased with gumming disease.

are not well defined and identification is often difficult. In the chronic phase the chief symptom is the presence of long narrow white to cream stripes on the leaves. These stripes are very straight and regular in outline and, like the yellow streaks of gumming, follow the direction of the main veins and arise at a slight angle to the midrib. The width of the streaks varies from about $\frac{1}{8}$ inch to a barely visible line, but older streaks become broader and less definite in outline, and finally the area within the boundaries of the streak becomes withered and dried. The withering usually commences at the margin of the leaf and proceeds inwards, thereby giving to the leaf the "scalded" appearance from which the name of the disease is derived (*see* Plate II.). This withering is most marked during dry spells. The streaks of leaf-scald, unlike those of gumming disease, can usually be readily traced down the sheath of the leaf where they often assume a light-purplish colour. In later stages of the disease the stalk may produce numerous side shoots, the leaves of which bear the typical fine whitish stripes. In the final stages, in susceptible varieties, the stalk dies (*see* Fig. 116).



[*Photo. by D. S. North.*

FIG. 116.—Stalk of cane showing advanced stage of leaf-scald disease. The top is bunched up, the leaves are white and scalded (especially at tips and margins) and side shoots have been produced. The side shoots often bear fine white lines similar to those described for top leaves.

Like gumming disease, leaf-scald is caused by bacteria which live in the veins and fibres of the cane, at least in the early stages. The chief method by means of which the disease is spread is that of knife

infection when cutting plants; after the knife has been used to cut a diseased sett it will serve to infect a number of subsequent setts.

Since knife infection is the chief method of spread, the disease can be controlled in all but the most susceptible varieties by planting disease-free plants which have been cut with a knife which has previously stood in boiling water for ten minutes. For the proper control of this disease the farmer is advised to maintain a farm nursery plot, as far removed from his other cane as possible, and to plant his fields with cane from the plot. This nursery plot should be planted with known healthy plants and special knives should be kept for the harvesting of this cane and cutting it into plants. Knives should be sterilized periodically by standing in hot water for ten minutes. The resistant varieties available are set out in Table I.

Red Stripe (Top Rot).

Red stripe disease is also commonly known by farmers as "top rot," but as there are a number of other diseases which finally produce a rotting of the top of the cane it saves confusion to refer to this particular one as red stripe. The disease is found, at times, over the whole of the sugar belt, but appreciable damage is confined to parts of the Mackay and Lower Burdekin districts, and, more particularly, the area north of Townsville. It is a wet-season disease but is most commonly found following a dry spring when cane has been severely checked.

As in the case of gumming disease, red stripe is primarily a leaf disease, but in susceptible varieties the disease may pass down into the stalk and set up an evil-smelling rot of the stalk top. After the first spring rains the presence of the disease manifests itself by the production of narrow dark-red streaks running along the leaves between the veins. Individual streaks are usually about 1/16 inch in width, but several streaks may run together to give quite broad dark-red bands, particularly towards the base of the leaf. Stripes may arise in any portion of the leaf but the majority are formed towards the base. As they become older the colour of the stripes deepens until they are a chocolate-red. On the under surface of the strips may be noticed small whitish blotches which result from the drying of a fluid which oozes out of the pores of the leaf in that position; this fluid contains millions of the bacteria which cause the disease (*see* Plate III.). The disease may not progress beyond the leaf-stripe stage, but when it does a very unpleasant and characteristic odour follows the rotting of the stalk top, which usually occurs during January-March.

It has been noted previously that this is also a bacterial disease but, unlike gumming and leaf-scald, the bacteria normally live between the veins. They can also live in the soil and dried trash for periods of time and are there ready to set up infection as soon as conditions are favourable. The bacteria ooze out of the pores on the under-surface of the leaves at night and are splashed and blown on to the leaves of healthy cane, enter similar pores in the leaves, and so set up infection in the new plant. It may thus spread through a field with great rapidity, and a field of a susceptible variety may soon look as though it has been sprayed with red paint.

Red stripe may be controlled through the use of resistant varieties (see Table I.), but varieties of the same degree of resistance as Badila may be very satisfactorily grown provided suitable precautions are taken.

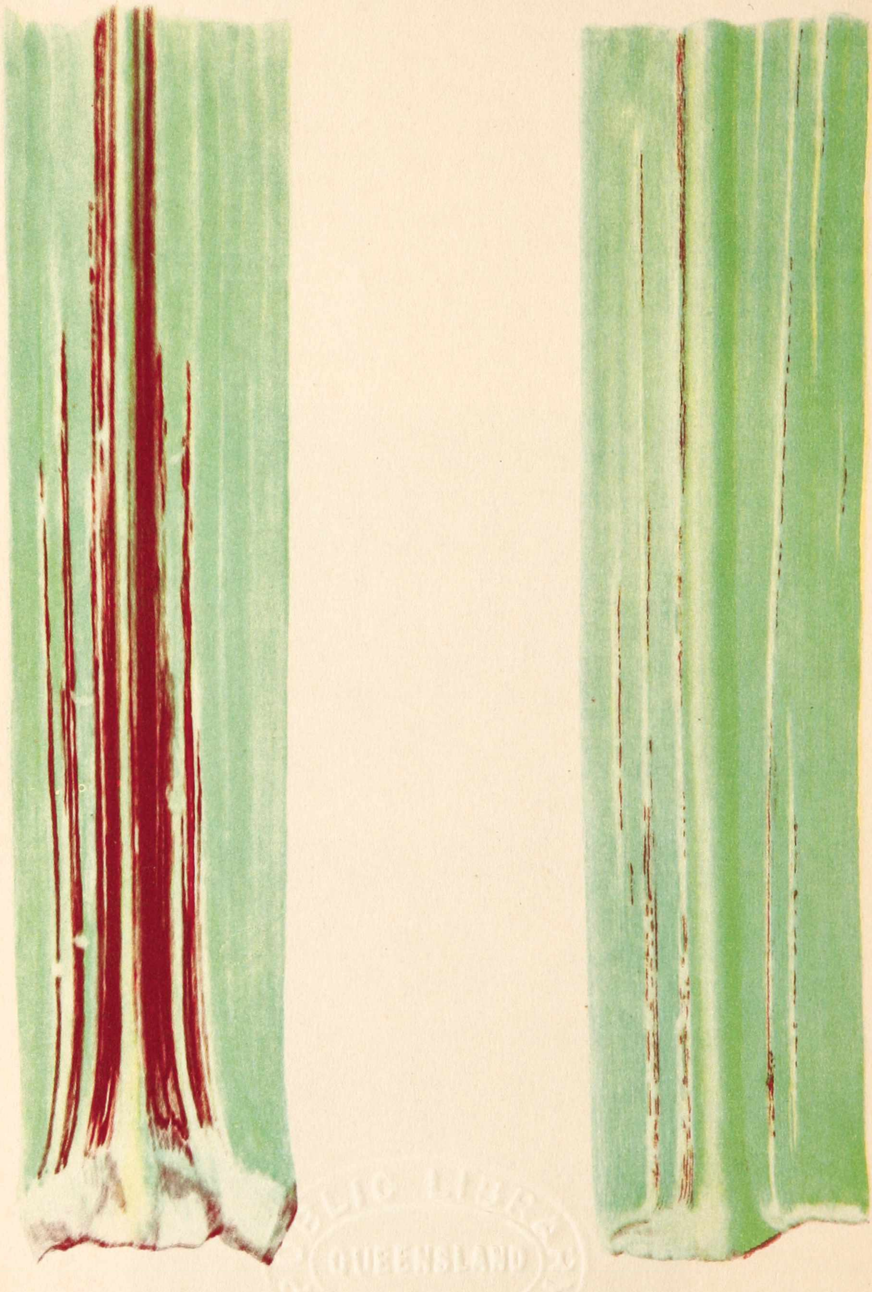


Plate III.

Red Stripe (Top Rot) Disease.—The left-hand leaf shows the narrow dark blood-red leaf streaks of red stripe disease; note also whitish blotches of dried bacterial ooze. The right-hand leaf shows the yellowish streaks of the unimportant mottled stripe disease.

Early-planted cane is very much less susceptible than late-planted cane, and hence where the disease is prevalent the planting of susceptible varieties should be done in the autumn. Soils which do not retain moisture will produce crops of greater susceptibility and patches of such soil should be planted to resistant varieties. The too close planting of setts, and the too heavy application of fertilizers, which cause an over-crowding of stalks, are conditions which favour the disease and they should be avoided.

This disease is very spectacular in its attack and, as a result, is credited with being much more serious than is actually the case. Provided the disease does not pass beyond the leaf-stripe stage it can do no appreciable damage. As far as the top rot is concerned, it must be remembered that, even in the absence of diseases and pests, only about 40 per cent. of the shoots which come through the ground actually make cane and so, to a great extent, the disease merely effects a thinning out which would take place anyway. Furthermore, even when the "thinning out" is excessive the remaining stalks compensate in some measure by producing more cane. The earlier death takes place the greater this amount of compensating growth, but it is usually not less than 50 per cent.; that is to say, 10 per cent. death will not commonly cause as much as 5 per cent. loss of crop.

Chlorotic Streak.

Chlorotic streak is one of the most recently recorded diseases in Queensland, but current experiments indicate that it is economically a quite serious disease in the important area north of Townsville. It was first recognised as a distinct disease in 1929, having previously been confused with leaf-scald; for this reason it is also sometimes referred to as pseudo-scald. It is found in Badila throughout North Queensland and has been reported from fields of Badila in a few isolated farms south of Townsville.

The disease lacks conspicuous symptoms, and even those available are often difficult to find. The leaf symptoms as found in Badila are illustrated on Plate IV. They consist of narrow cream to white longitudinal streaks on the blade of the leaf, ranging in width from 1/16 to 3/16 inch. They follow the general direction of the leaf veins, but are rarely of uniform width and have a wavy outline and are often fragmented, thus distinguishing the streaks from those of leaf-scald. They may run the whole length of the leaf blade, but are frequently quite short. In older streaks the area within the streak may die and take on an ashy-grey colour, surrounded by a narrow reddish border (*see* leaf illustrated on right of Plate IV.), but this scalding does not extend outwards beyond the original boundaries of the streak as in the case of leaf-scald. The streaks are best found during the period October-December, but even then there may be found only one or two streaks per stool. From December onwards the symptoms gradually disappear in Badila, and by February it is frequently impossible to find a single streak in a field known to be virtually 100 per cent. diseased. Young diseased cane, both plant and ratoon, shows a marked tendency to wilt, even in the presence of excess moisture, but this phase soon passes. Leaves and sheaths of young diseased cane may also assume a reddish hue over a considerable proportion of the surface.

No visible organism is associated with the cause of this disease, and it is possibly related to diseases of the virus type such as mosaic and Fiji. So far the investigation into the manner of spread of the

Plate IV.

CHLOROTIC STREAK DISEASE.—Leaf streaks of this disease are similar to those of leaf-scald (Plate II.) but are irregular in outline and width, are often fragmented, and when dead areas develop in the streak they do not extend beyond the original width of the streak.

disease has not been successful, but apparently it is not spread mechanically by cane knives, &c. Laboratory experiments, and field trials carried out on farms at Meerawa and Tully, show that a loss of about 25 per cent. in weight of crop is to be expected when diseased setts of Badila are planted. The disease has been recorded in all the major varieties now grown in North Queensland. The method of control advocated at the present is the use of healthy cane for planting purposes, such cane to be selected on the advice of the field officers of the Bureau. A number of plantings of healthy cane have been made in various localities, and these indicate that spread of the disease is most rapid in the low-lying areas of the high rainfall belts. On the other hand, apparent spread takes place very slowly, if at all, on the elevated red soils. Consequently these elevated areas should provide the best sites for the propagation of disease-free cane obtained from approved sources.

The disease is very readily controlled by warm water treatment of setts. Immersion in warm water for 20 minutes at 125 degrees Fahrenheit will ensure that cuttings from diseased plants will give rise to a healthy plant crop; the temperature must be strictly controlled. There are certain difficulties in the way of mass treatment of cuttings in this manner, so that it would require to be a co-operative effort.

Mosaic Disease.

Mosaic is one of the most widespread of cane diseases and has been reported from virtually every cane-growing country. In recent years it has been responsible for spectacular epidemics in Puerto Rico and Louisiana, in both of which countries there was an astounding decrease in production and the industries were for a time threatened with extinction. The disease has been found all over Queensland, but is of no consequence in the wet tropical belt and is causing losses only in certain areas in the Mackay, Proserpine, and Bundaberg districts.

The outstanding feature of mosaic disease is the presence of a curious mottled pattern on the leaves of diseased plants, which is caused by the contrast of light-green to yellow blotches against the normal darker-green of the remainder of the leaf (*see* Fig. 117). These light-coloured areas are irregular in size and shape, but their long axis runs in the general direction of the long axis of the leaf, thus causing a somewhat striped appearance. The pattern is most distinct on the youngest leaves and gradually becomes indistinct on passing out to the oldest leaves. These symptoms of mosaic disease are more easily observed on dull days than on bright sunny days. In addition to the leaf markings there may also be found a mottling of the stem, but as this does not occur until later stages of the disease, it is not a particularly useful symptom. The effect of mosaic disease is to cause a stunting of the affected plants; this may range from a barely appreciable loss in weight to death of the plant, depending on the variety.

Mosaic is a virus disease caused by an agency too small to be seen with the most powerful microscopes. It is spread from plant to plant mainly by the corn aphis, a small dark insect often seen in great numbers on corn tassels; this insect also thrives on numerous wild and cultivated grasses, but does not live on sugar-cane, on which it feeds only by accident.

Since mosaic disease is spread by insects which are brought into the canefields on weeds, or from nearby corn or sorghum fields, it is obvious that the first step in the control of the disease is to keep the fields and their surroundings free from such weeds and grasses which serve as breeding grounds for the aphis. In most places 100 per cent. control may be obtained by selecting healthy plants, digging

FIG. 117.—Mottled pattern on leaves of mosaic-disease-infested cane caused by irregular loss of normal green colouring.

out any diseased stools which may appear in the young plant cane, and keeping down the weeds on the fields and headlands. In some places, however, especially on the fringe of cane areas, the rate of spread is too rapid for these methods to succeed. The situation may then be controlled by early planting or, failing that, by the use of some of the resistant varieties listed in Table I.

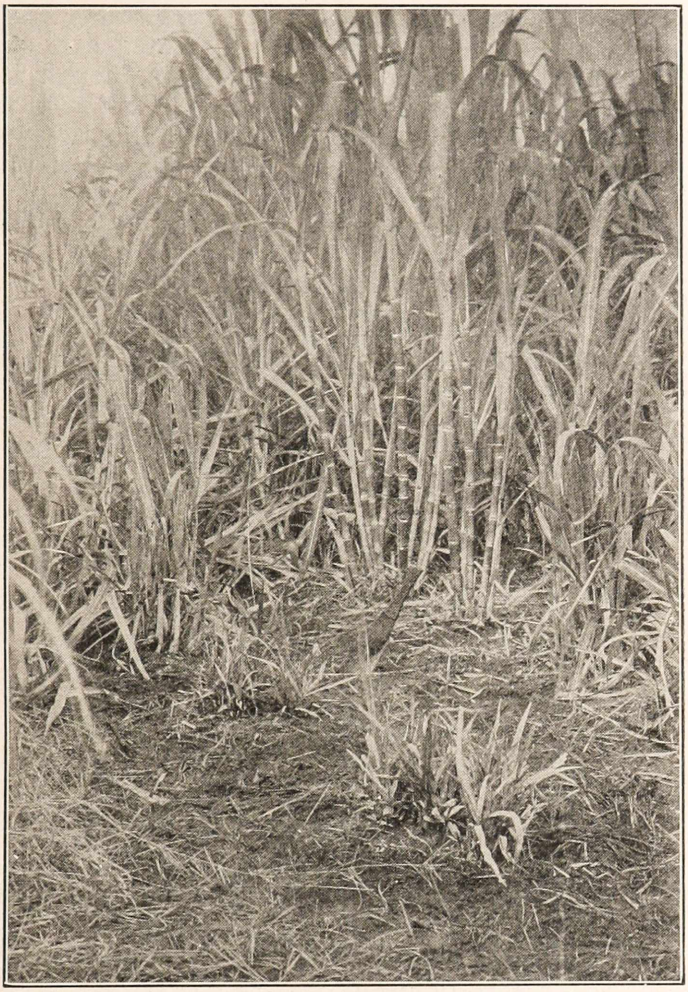


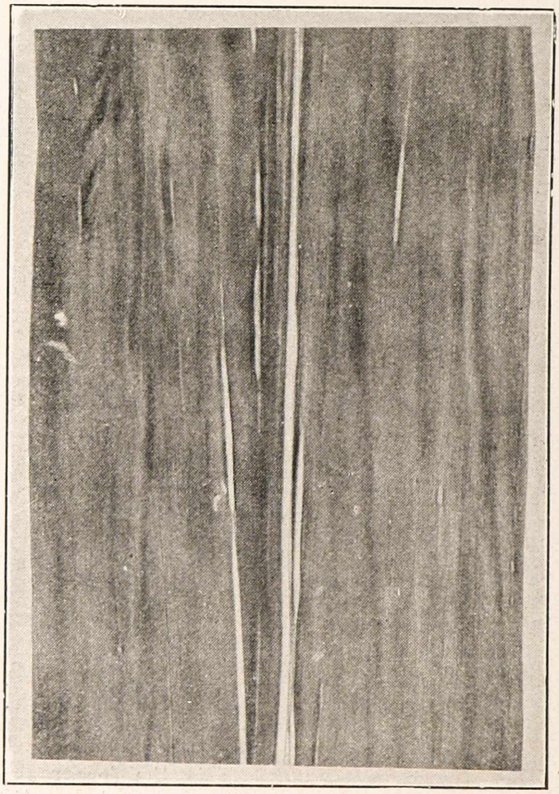
Fig. 118.—The two small grass-like stools in the foreground are the result of ratooning Fiji diseased stools; the planting of infected cuttings of susceptible varieties yields a similar type of plant. This stage of this disease is very similar to dwarf disease (*see* page 163).

Fiji Disease.

Fiji disease is so called because it was first found some thirty odd years ago in the colony of that name; the disease had disastrous consequences for the Fijian industry and for a number of years caused great losses. In Queensland it is generally distributed throughout the Maryborough and Logan areas and is spreading slowly in the Bundaberg-Childers and Moreton districts.

Although this disease is somewhat difficult to describe accurately it is extremely easy to recognise if a person has once seen a good specimen. When a diseased sett is planted the plant which results

consists usually of a grass-like clump of stunted leaves and makes no cane at all; in this stage it very closely resembles dwarf disease in general appearance (*see* Fig. 121). On examining the underside of such leaves it will be seen that there are present small swellings or galls varying in diameter from about $\frac{1}{32}$ inch to about $\frac{1}{16}$ inch, by $\frac{1}{4}$ to $\frac{1}{2}$ inch long. These galls are illustrated in Fig. 119, and their presence removes all doubt as to the disease being Fiji disease. When growing plants become infected after germination the diseased stalks cease to make further upward growth, the leaves become stunted and stiff, tend to curl upwards, and the whole cane top looks as though it had been bitten off by some animal. Such a diseased cane is illustrated in Fig. 120. On examining the under surface of these stunted leaves the small galls described above can be found; they may not be numerous but they are readily seen on most of the leaves.



[*Photo. by J. P. Martin.*

FIG. 119.—Small galls on under surface of leaf of sugar-cane affected with Fiji disease. These galls, which are shown at actual size, are swellings on the veins of the leaves and resemble varicose veins.

A condition known as "clustered stool" resembles the small stunted stools which arise as a result of planting, or ratooning, Fiji disease plants (*see* Fig. 118). This is common in P.O.J. 2878. It may readily be distinguished from Fiji disease, however, by virtue of the fact that no small galls are present on the under surface of the small leaves.

Like mosaic this is a virus disease, and it is spread from diseased to healthy plants by the sugar-cane leaf-hopper; unlike the corn aphis this insect feeds mainly on sugar-cane.

FIG. 120.—Stiff, stunted, and malformed leaves typical of a well-advanced stage of Fiji disease when the plant has become infected after germination. Note the appearance of the top having been eaten by some animal.

As far as is known, Fiji disease does not attack other plants and, therefore, it is satisfactorily controlled by the careful selection of planting material and the digging out of diseased plants as soon as they are observed. Unfortunately, the symptoms of this disease may remain masked for long periods of time, especially during the winter months, and consequently two or three inspections, spread out over the year, are necessary to be certain that a field is disease free. As far as possible plants should only be taken from a field in which no diseased stools have been seen after careful inspections; as Fiji disease spreads much more rapidly in well-grown crops it is a good point to take plants from poor land if possible. The young plant cane should be inspected early and often, and diseased stools dug out immediately, as the leaf hopper becomes very numerous as soon as the late spring and summer rains occur. Crops in which the disease has appeared should be ploughed out immediately after the last cutting, and not allowed to volunteer and act as a source of infection for other crops.

FIG. 121.—Small grass-like shoots produced by planting setts of dwarf diseased P.O.J. 2714. The stools shown here are nine months old and greatly resemble Fiji disease (*see* Fig. 118).

Very few varieties of sugar-cane are known to be highly resistant to Fiji disease, but, on the other hand, numerous varieties are very highly

susceptible. Chief among the latter are the new P.O.J. canes, some of which show such promise in other respects. These canes are so susceptible that their growth in areas where the disease is common will only serve to increase the intensity of the disease and so become a menace to other varieties. Where spread of the disease is rapid, resistant varieties should be planted after a study of Table I.

Dwarf Disease.

Dwarf disease is one of the newest of the world's sugar-cane diseases, having been found in the Mackay district in 1930. As far as is known the disease is confined to farms in the low-lying country in and around the Rosella district.

FIG. 122.—Dwarf disease. Stiff, stunted, fan-like top developed on a cane stalk which has become infected after germination.

When diseased cuttings are planted they give rise to plants which at first sight very closely resemble those grown from Fiji-diseased cuttings. That is to say, the stools consist of a cluster of grass-like shoots (*see* Fig. 121), but, instead of the stunted leaves bearing galls (*see* Fig. 119, p. 160), they bear fine irregular yellow stripes. In later stages the margin of these leaves becomes scalded and ragged and numbers of the shoots soon die. When the growing plant is attacked, further upward growth soon ceases, the cane top pinches off to a point and the leaves stand out stiff and fan-like (*see* Fig. 122). These leaves bear the typical fine yellowish stripes, particularly towards the base. The stripes are irregular in outline, about $\frac{1}{16}$ inch wide, and are usually about $\frac{1}{2}$ to

FIG. 123.—Fine, yellowish, broken and unevenly distributed streaks, indicative of dwarf disease.

2 inches long, but may extend up to 6 inches in length (*see* Fig. 123). They are not evenly distributed over the surface of the leaf and at times may run together to give yellowish bands of $\frac{1}{4}$ to $\frac{1}{2}$ inch in width. As in the case of the mottled pattern in mosaic, the stripes tend to become obliterated in the oldest leaves. As the disease progresses the younger leaves in the heart of the cane top become quite yellow in colour, and are short, twisted, and deformed. Finally the stalk may die.

This new disease is of the virus disease type in appearance, and it is expected that some insect will be found to be the spreading agent. This aspect of the disease is now being investigated in Mackay. So far the disease has been found in the following varieties:—P.O.J. 2714 (especially), Clark's Seedling, Malagache, E.K. 28, and P.O.J. 213, and these varieties should not be grown in those fields where the disease appears. Particular care should be taken with P.O.J. 2714 and plants of this and other varieties should certainly not be taken from the Rosella district.

Apart from the cessation of planting susceptible varieties (listed above) in fields where the disease appears, no control measures appear necessary at this juncture. Continuous observations indicate that the disease is not only confined to Rosella but to low-lying fields or even parts of fields within this area. Accordingly it is felt that there is at present no cause for alarm regarding the possible consequences of the presence of this disease.

Downy Mildew.

Downy mildew is also known as leaf stripe disease. It is found in all parts of Queensland, but until recently was responsible for damage only in the Lower Burdekin area and in a few isolated fields in Mackay. With widespread plantings of the susceptible P.O.J. canes, however, it has assumed a new importance, especially in the Mackay and Bundaberg districts. Indeed, owing to the susceptibility of the P.O.J. canes, and the seedlings bred from them, downy mildew may well be regarded as the most serious disease of sugar-cane in Queensland.

This disease is characterised by the presence of long, well-defined yellowish stripes on the leaves. One to numerous streaks may appear on each leaf (*see* Plate V. and Fig. 124); they vary in width from about $\frac{1}{10}$ inch upwards, separated by strips of normal green leaf, but they may run together to give a continuous broad yellow band. These stripes may be observed on the youngest leaves, but become more distinct as the leaf grows older, while in the oldest leaves the yellow becomes plentifully blotched with red and later turns brown. In humid weather the under surface of these leaves is seen to be covered with a soft white down of fungus growth (*see* inset Fig. 124). These symptoms are most conspicuous in the wet season. In the winter months a certain proportion of the diseased stalks elongate as though they were going to arrow, and stand out like flags some 2 to 3 feet above the rest of the cane. This is called the "jump-up" stage of the disease; these elongated stems are very thin, watery, and brittle, while the leaves are stunted, stiff, and sparse, and later become very much shredded and twisted.

Downy mildew is caused by a fungus the spores or "seeds" of which are carried in the wind. Infection takes place in the eyes of the stalk during wet weather, the fungus spores germinating and penetrating the soft young buds. After a stalk has become infected

Plate V.

DOWNY MILDEW DISEASE.—From left to right, successive stages of downy mildew disease. The yellowish leaf streaks are very irregular in length and width; they later become blotched with red and finally almost the whole leaf may become reddish in colour.

in this way the fungus may not spread up to the growing point of the stalk and so the top may remain perfectly healthy, although the stalk is actually diseased and would yield diseased plants if planted.

FIG. 124.—Downy mildew disease; see also Plate V. The characteristic long yellowish leaf stripes have irregular, but well-defined, margins. On the under surface of diseased leaves may be borne a white fungus growth as shown (magnified) in the inset.

Control is based on plant selection, field sanitation, and the use of resistant varieties. Owing to the failure of symptoms to appear in the diseased canes in all cases, as outlined in the last paragraph, plants of susceptible varieties cannot be selected within a diseased field and should not be taken from within 200 yards of the nearest diseased stool. The young plant cane should be carefully and periodically inspected, and diseased plants rooted out; the disease does not spread to any extent during the dry season of the year, and this is the time to get rid of it. Fields in which the disease has appeared should be ploughed out as soon as the final crop has been harvested and not allowed to volunteer and act as a source of infection for other crops. Recent investigations

have indicated that maize contracts the disease readily and should on no account be grown in the neighbourhood of fields of susceptible cane varieties.

Stem Rots.

Red rot is possibly the most widespread of stem rot diseases and is found in most parts of the cane world. It is found in all parts of Queensland, but, as a rule, is of importance only in the Mackay and, to a less extent, the Lower Burdekin districts.

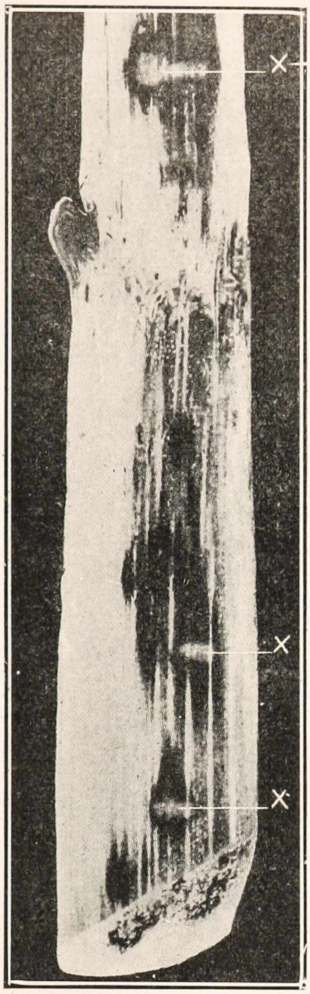


FIG. 125.—Dark red discoloration of flesh of stem caused by red rot disease. At "x" are shown the curious white patches within the reddish areas peculiar to this disease.

The early symptoms of red rot are hard to detect unless the observer is a specialist. The cane leaves exhibit a premature wilting and dying which may culminate in the death of a large proportion of the stalks. On splitting open diseased canes there is found a marked reddish discoloration of the "flesh," particularly at the base of the stalk. The colour is, as a rule, not evenly distributed; darker patches alternate with lighter patches (*see* Fig. 125). A peculiar characteristic of this disease is that in the dark-red blotches there often appear white patches; these have their long axis across the stem and are caused by the cells being filled with air (*see* Fig. 125). In the final stages the pith dries up and becomes a dirty brown-mud colour.

Red rot is caused by a fungus which enters the cane through cracks or wounds in the stem and buds. The fungus is ever present in the fields awaiting suitable conditions for attacking the cane, and so plant selection is of little use for its control. Nevertheless, red rot diseased cane germinates badly, and any cane with a red discoloration should be discarded when plants are cut.

As will be seen by reference to Table I., there are a number of varieties which are quite resistant to red rot. Even in the susceptible

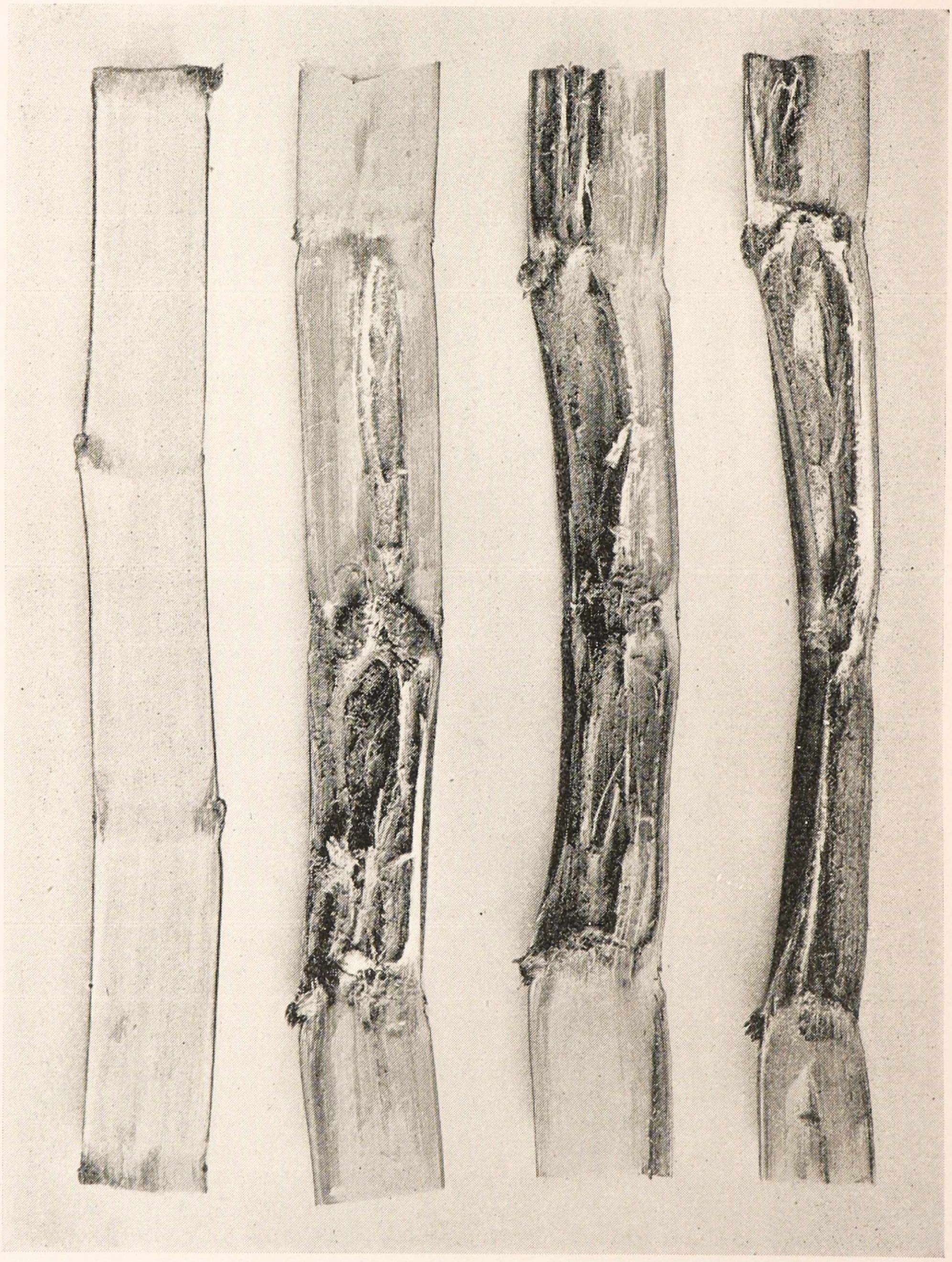


FIG. 126.—Reddish discoloration of flesh and shrunken stems, characteristic of rind disease; normal cane on left.

varieties, however, the disease is, as a rule, only severe on over-ripe crops and, except in very dry seasons, can be controlled by cutting the cane before it is over-mature. Care should be taken to see that there is not too great a proportion of early or mid-season maturing varieties grown on the farm, so as to ensure that each can be cut at its proper time. The date of the commencement of crushing of mills is an important factor in this respect and should be borne in mind when the crushing dates are arranged. In very dry seasons, or in soils where the subsoil is coarse, the disease is much more pronounced, and under these conditions late maturing varieties may be attacked before reaching maturity.

Somewhat resembling red rot is rind disease, which was very prevalent in most districts during the very dry 1937 crushing season, but particularly so in S.J. 4 in North Queensland and standover P.O.J. 2878 in South Queensland. This disease is also due to a fungus which causes an internal reddish rot of the stem (but without the lighter patches found in red rot (*see* Fig. 126)). In later stages the pith turns dark in colour and dries out, causing affected internodes to shrink and sometimes split. As a rule the affection starts a few internodes above the ground, the butt remaining apparently healthy. One to several internodes may be attacked, but as a rule only three or four are badly affected. The general remarks on occurrence and control of red rot apply also to this disease.

The Cane-killing Weed.

The cane-killing weed has been found in most districts south of Townsville and has occasionally caused considerable losses in particular fields in the Lower Burdekin and Mackay districts. It is indigenous to this country and we have on several occasions found it associated with the wild grasses on which it must have existed before the introduction of sugar-cane.

It is a parasite of the roots of sugar-cane and may cause severe stunting of the cane plant, followed by death if the infestation is heavy. As a rule, the areas of infection are roughly circular in shape, with a diameter of a few yards. In a typical case the stools are much stunted, with sparse tops and clinging trash; the young green leaves stand out stiffly from the crown, while the dead leaves stand out or hang stiffly from the stem. The clinging trash is often responsible for the development of aerial roots upon the stalk.

When such patches of stunted or dead cane are found during the summer months a search around the base of the stools will reveal clusters of the weed (*see* Fig. 127) around the stools or even in the inter-spaces. The leaves and stems of the weed are green in colour, the leaves being small and narrow. Flowering takes place freely during the late summer; the flowers are small, without stalks, and light-blue to pink in colour. The plants may trail along the ground or grow upright, in the latter case being up to about 2 feet in height.

In autumn the plants die off and both stem and leaves take on a bluish colour. Small seeds about 1/32 inch long are borne in large numbers in small capsules.

On carefully digging up a stool of cane, with the associated weeds, it will be found that some of the roots of the weed are definitely attached to those of the cane plant; in this way the weeds rob the cane plant of food and probably also inject poisonous substances into it.

The cane-killing weed is an annual and the whole plant dies after flowering and production of seed. The seeds are easily carried by wind and irrigation water and germinate when they come in contact with the cane roots.

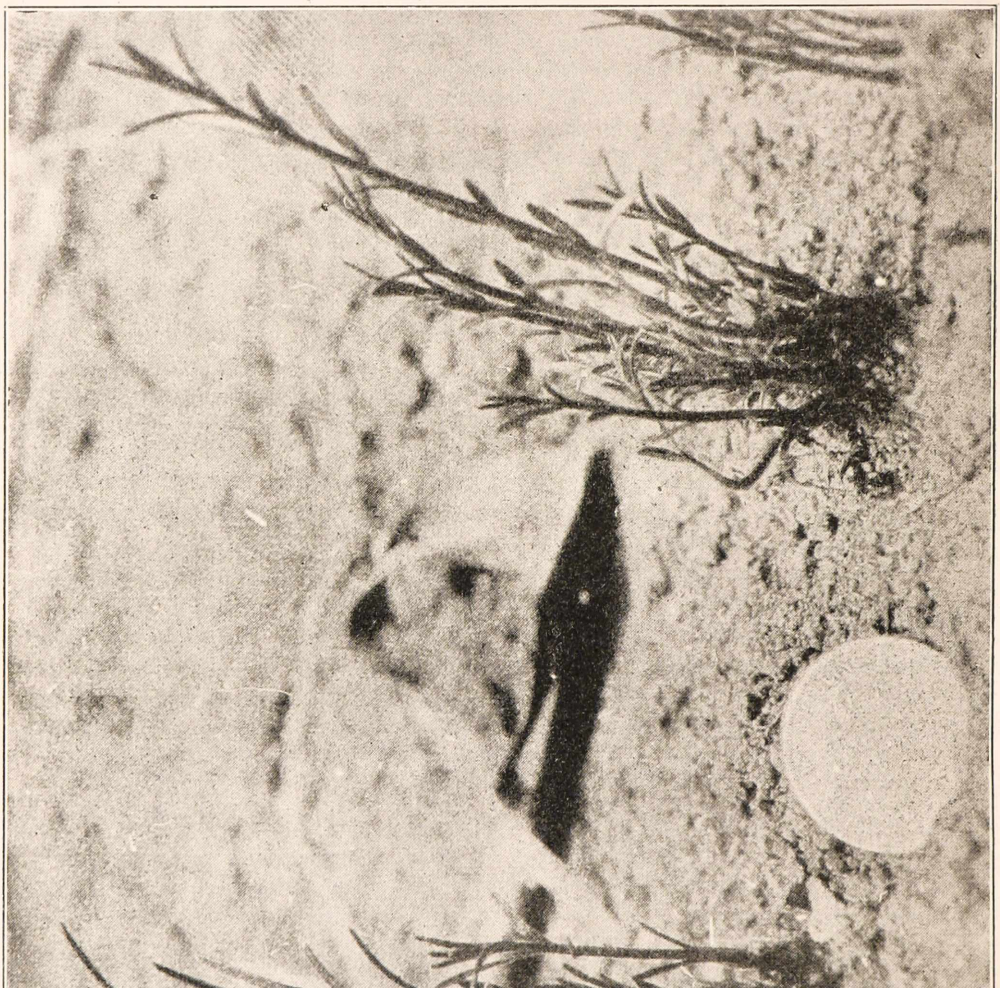


Fig. 127.—A cluster of the cane-killing weeds at the base of stool of cane.

Control may be effected by carefully and repeatedly chipping affected patches so as to prevent the weed from seeding. The seeds are sensitive to heat and any affected fields should be burnt before harvesting. If the patches are large the crop should be ploughed out after harvesting and the field rotated for a year to leguminous crops which are not attacked. During this time no fresh seed will be set and old seeds will gradually lose their viability.

Variety.	Gumming.	Leaf Scald.	Red Stripe.	Mosaic.	Fiji.	Downy Mildew.	Red Rot.
Northern District—	Present in Gordonvale and Ingham line areas.			Practically not present.	Not present.		
Badila (N.G. 15)	2	2	2			1–2	1
B. 147	1	1	1			2	1–2
D. 1135	2–3	1	1			2	1
H.Q. 409	1–2	2	1			2	–
H.Q. 426 (Clark's Seedling)	3	3	1			1	2
H.Q. 458	2	2	–			–	–
Korpi	1	2	1–2			2	–
Nanemo	1	2	–			–	–
Oramboo	1	2	2			–	–
Pompey (7 R. 428)	3	2–3	1			2	1
P.O.J. 2878	1	1–2	3			2–3	–
Q. 2	2	1–2	1			–	–
Q. 10	1–2	1–2	1			–	–
Q. 813	1	1	1			1–2	1
S.J. 4	3	2	2			–	–
Central District—(including Giru and Lower Burdekin) :—					Not present.		
Badila (N.G. 15)	2–3	2	2	2		1–2	2
Co. 290	1	–	–	2–3		–	–
D. 1135	2–3	1	1	3		2	1
E.K. 28	3	3	1	2–3		2	1
H.Q. 285	2–3	–	–	2–3		–	2
H.Q. 426 (Clark's Seedling)	3	3	1	3		1	2
Korpi	1	2	1	2		2	–
M. 189 (Black Innes)	2	1	–	3		2	2
M. 1900 S.	3	–	2	3		2	2
Oramboo	1	2	2	2–3		–	–
P.O.J. 2714	3	–	2–3	1		2–3	2
P.O.J. 2725	1	–	1	1		1	–
P.O.J. 2878	1	1–2	2–3	1		2–3	2
Q. 20	1	–	1–2	–		1–2	–
Q. 813	1	1	1	2		1	1
S.J. 2	3	2–3	2	–		–	2
S.J. 4	3	2	2	2–3		–	2
S.J. 7	2–3	3	2	–		–	–
Southern District—		Not present.	Rarely of any importance.				Rarely of any importance.
Co. 290	1			1–	1–2	2	
H.Q. 285	2–3			2–3	1–2	1–2	
Korpi	1			2	2	1–2	
Mahona (N.G. 22)	3			2	2	–	
Oramboo	1			2	2	1–2	
P.O.J. 213	1			2–3	1	2–3	
P.O.J. 234	1			2–3	1	2–3	
P.O.J. 2725	1			1	3	2	
P.O.J. 2875	1			–	3	2–3	
P.O.J. 2878	1			1	3	2–3	
Q. 25	1			–	2	1–2	
Q. 813	1			2	2	2	

TABLE I.—Approximate standard of resistance of approved and promising experimental varieties to the diseases of each district (1939). It will be noted that the resistance of a variety may vary somewhat from district to district, according to climatic conditions.

1. Highly resistant and may be grown in the presence of the disease without precautions.
2. Moderately resistant, and may be grown in the presence of the disease provided suitable precautions are taken.
3. Susceptible, and should not be grown in the presence of the disease.

– Insufficient observations to permit of classification.

Chapter XIV.—INSECT PESTS OF SUGAR-CANE.

INTRODUCTION.

Few economically important insect pests of sugar-cane have been introduced into Queensland from abroad, but, unfortunately, the indigenous insects include the majority of the most destructive pests of this crop. As in the case of the diseases of sugar-cane, so is the Queensland canegrower faced with entomological problems probably more complex than those existent in any other cane sugar-producing zone.

All portions of the cane plant are subject to destructive insect attack, the severity of the attack of each particular type varying according to season and locality. Several species of white grubs devour the roots and cause a partial or complete cessation of the passage of water and food into the plant; wireworms may eat into the sett buds and young shoots and prevent satisfactory germination; the stem is attacked by borers, which destroy the soft, sweet pith of the cane and open the way for the entry of the causal agents of such internal diseases as red rot; army worms and other caterpillars and grasshoppers may devour the leaves, thereby causing serious stunting of the plants, while moth borers may destroy the growing point of the cane and cause its death. Finally, in the last few years, insects have been shown to provide a further menace inasmuch as they are responsible for the spread of diseases of the virus type such as mosaic and Fiji diseases.

CONTROL OF INSECT PESTS.

Mankind is forced to wage continuous warfare upon the insects in order to protect himself and his food supplies from destruction, and the methods of insect control which have been devised are many and varied. In this section will be discussed in a general way the broad principles of insect control as applied to sugar-cane pests, while the specific application of the methods to particular pests will be treated in the succeeding section. The methods available may be conveniently discussed under four different heads—namely, cultural, chemical, biological, and legislative methods.

Cultural Control.

Control of insect pests by cultural methods includes all means whereby conditions may be made more favourable to the crop, or less favourable to the insect, by some adjustment of agricultural practices, whether it be time and method of ploughing, selection of variety, rotation of crops, or any other of the numerous farm operations. Probably the oldest and most commonly used method is that of the destruction of insects by farm implements or the hand collection of insects exposed during the cultivation of the land. The success of such methods naturally depends upon the ratio between the number of insects destroyed and the number left untouched in any particular area, and success, as a rule, is only achieved in compact areas where vast numbers are destroyed or collected. Huge sums of money have been expended in the collection of cane beetles and grubs in the past, and unquestionably a great deal of this money has been wasted.

Variation of time of planting may often enable a crop to escape the attack of particular insect pests, either by planting later to avoid the period of greatest activity of insects which attack setts or the young plants, or by planting early in order to get the crop beyond the susceptible stage at the time of activity of some pest. In North Queensland late-planted cane is less subject to grub attack than the more advanced early-planted cane.

Clean cultivation is frequently of great assistance in reducing the numbers of insect pests such as moth borers and many sap-sucking insects. Crop rotation is also employed with success in certain cases but would not be of value as a means of dealing with any of the important cane pests of Queensland. Burning of trash may be of considerable aid in reducing the numbers of pests such as beetle borers and army worms; on the other hand the burning of trash also destroys beneficial parasites, while the conservation of trash serves to improve the fertility of the soil. This measure, therefore, should only be employed after full consideration of all factors.

The use of resistant varieties does not offer anything like the same possibilities in insect control as it does in the control of diseases. Nevertheless, a considerable amount may be done in this direction and the question is now receiving due attention. The variety S.J.4, a sugar-cane seedling raised by the Bureau of Sugar Experiment Stations, has shown markedly higher powers of resistance to grub attack of light to moderate intensity in North Queensland than that possessed by the old standard canes. Susceptibility to borer and rat damage may also be combated in part by the development of canes with harder rinds.

Chemical Control.

Methods for the control of insects by the application of chemicals as stomach poisons, contact poisons, and fumigants are in common usage in house and field. The first-named are used in the control of insects (grasshoppers and caterpillars for example) which bite and chew their food. In such cases food is coated or impregnated with poison so as to induce the insects to consume a certain amount while feeding. Insects which obtain their food by piercing the outer covering and sucking the juices from within the plant would, of course, be unaffected by poisons coating the exterior of the plant, and for their destruction contact poisons must be used. These are usually sprays composed of oil, nicotine sulphate, &c. which act through the breathing organs or penetrate the external covering of the insect and so bring about its death. The numerous scale insect and aphis sprays are of this type.

Fumigants are volatile substances which evaporate and bring about the asphyxiation of the insects, and are especially useful in attacking insects which cannot be reached by stomach or contact poisons. The injection of carbon disulphide and paradichlorobenzene into the soil to destroy the cane root-eating grubs is a well known example of this form of control.

Biological Control.

Owing to the spectacular success which has attended campaigns for the control of the sugar-cane leaf-hopper in Hawaii, the cocoanut moth in Fiji, the prickly-pear in Australia, and similar rather isolated instances, biological control of plant and insect pests has attained a

much greater degree of popularity with the general public than is justified by its history. Speaking generally we find in nature the following chain of relationships:—The plant or animal host—the insect pest which attacks it—the parasite which keeps the insect pest in check—and the hyperparasite which in its turn preys upon the parasite. Over long periods of time the relations between the members of the chain have reached a state of balance where all survive and none increase greatly at the expense of another. If, now, the pest is suddenly transported to a new country, but without the parasites which keep it in check in its native country, it is obvious that it may do untold damage in its new home. Such was the case with the sugar-cane leaf-hopper, which was introduced into Hawaii without its natural parasites and which soon wrought havoc in the Hawaiian canefields—although of little importance in Australia. In such circumstances the natural procedure is to send entomologists to the country of origin of the pest and endeavour to introduce the parasites of this pest into the new country, *but without the hyperparasites which keep them in check at home.* Should this be achieved it follows that the parasites will have what is commonly termed an "open go" at the pest and soon reduce it to insignificant numbers. A very spectacular triumph is achieved and the stocks of biological control boom.

Unfortunately, this bright picture tells only a very small portion of the story and there are many reasons why biological methods of pest control, however desirable they might be, hold little promise for the Queensland sugar industry. In the first instance, most of our important pests are native to the country and so we find that well-established balance between pest, parasite, and hyperparasite; the arrival of the white race, which has brought about the cultivation of the land and the growing of succulent crops in place of native plants, has only served to improve conditions for the pest.

It usually happens that the parasites of any one pest will attack closely-related pests and so it might be suggested that parasites of allied pests should be imported from abroad for the control of, say, the Northern cane grub. Against this proposal, however, is the very high probability (especially in continental areas) that existing hyperparasites would attack the new parasites vigorously; furthermore there is also the ever-present possibility that there will be introduced a new hyperparasite which might increase the attack on the native parasites.

Pest, parasite, and hyperparasite are not equally affected by climatic changes, and consequently, even if all other conditions are favourable, an introduced parasite will frequently fail to become established on account of some unfavourable climatic condition. For the same reasons we get yearly fluctuations in the amount of insect attack, according as the weather conditions favour the one member of the chain more than the other.

Only one serious pest of sugar-cane in Queensland was introduced from abroad, namely, the beetle borer, which was brought in from New Guinea. It was found by Hawaiian entomologists that in New Guinea the borer was held in check by a Tachinid fly and consignments of this fly were imported into Queensland, where it exercises some control over the borer in certain areas where climatic conditions are favourable. Generally speaking, however, the degree of control is far from satisfactory.

In addition to being preyed upon by other insects, insect pests are attacked by various diseases and are eaten in vast numbers by birds and other animals. Consequently, every effort should be made to protect such animal life as aids in the suppression of these pests.

Legislative Control.

Legislative control of insect pests consists in the creation of quarantines in order to prevent the introduction of new pests from abroad, or to prevent the further spread of insects which have already gained entry. The same conditions apply as in the case of quarantines for the prevention of disease, and the reader is referred to page 146 for a full discussion of this subject.

QUEENSLAND CANE PESTS.

Below are considered in some detail the characteristics of the chief insect pests of sugar-cane in Queensland, together with the measures which are advocated for their control.

CANE BEETLES (ADULTS) AND GRUBS (LARVÆ).

Many different species of beetles and their grubs are found in Queensland cane fields, but only three are of much economic importance. These are:—(*a*) The Greyback beetle or Cockchafer (*L. albohirtum*), which is found throughout the northern cane fields from Mossman to the southern limits of the Mackay district; (*b*) French's Cane Beetle (*L. frenchi*), a widely distributed insect found in forest soils all along the Queensland coast; (*c*) The Childers Cane Beetle, found in the scrub soils of Isis, Gin Gin and Bundaberg, and as far south as Nambour.

The Greyback Beetle or Cockchafer.

The greyback beetle or cockchafer is the adult form of the grub known as the Northern cane grub, possibly the most destructive insect pest of sugar-cane in the world. The beetle is approximately $1\frac{1}{4}$-inches in length and $\frac{5}{8}$-inch in width. The colour of the wing cases is a deep chocolate brown but as they are thickly covered with white scales the insect has a greyish appearance. The beetle emerges from the ground during November and December after the ground has been softened by a suitable fall of rain. The newly emerged beetles fly to feeding trees (fig trees being particularly favoured) where they feed and mate. The female commences to lay her eggs about two weeks after emergence; these are deposited at the base of tunnels, at a depth of some 9-18 inches from the surface of the ground, and are laid in masses of 24-36. Although canefields are greatly favoured by the beetles for the laying of their eggs vast numbers are also laid in tracts of uncultivated lands. The eggs hatch after a period of about two weeks and the resultant grubs moult twice before attaining full size, thus giving three stages; the first stage lasts about four or five weeks, the second stage four weeks, while the third stage lasts some four to six months. Ability to determine the particular stage in which grubs are present is of importance in fixing time of fumigation (see later). This determination is made by reference to the head widths which remain constant between each moult, the width during the first stage being $\frac{1}{8}$ inch, the second $\frac{1}{4}$ inch, and the third $\frac{3}{8}$ in. The third stage grub is a creamy-white colour, but the tail end of

the body appears blue-black or chocolate, due to soil which has been taken in and which shows through the thin skin. The head is a brownish yellow colour and the upper part of the body bears a few stiff reddish hairs. The body is usually doubled up (*see* Plate VI.) and in this position is about 1¼ inches long when full grown, but when stretched out is a little over 2 inches long.

The grubs feed voraciously upon the cane roots, especially in the third stage. Feeding is usually finished by the end of June, when the grubs retire deeper into the soil in order to pupate. The pupal stage lasts until September-October, when the change to the beetle stage takes place, but these beetles remain in their cells awaiting soaking rains before tunnelling to the surface of the ground and commencing their life cycle once again.

As indicated above, the damage caused by this Northern cane grub is due to its devouring the cane roots, resulting in the partial or complete cutting off from the cane stools of supplies of water and plant foods. In the presence of small numbers of grubs damage may be restricted to a slight wilting and stunting, but with greater numbers the roots which anchor the stool in the ground may be completely severed and the stool collapses. Such fallen cane soon deteriorates and, since the damage takes place some two to three months before the commencement of the crushing season, it usually represents a complete loss. Moreover, should the crop be plant or first ratoon cane the farmer is forced to incur the additional expense of premature ploughing out and replanting of the field. The number of grubs which will suffice to bring about the collapse of cane in this manner ranges from an average of two or three grubs per stool in light soils to perhaps as many as six or eight grubs per stool in heavy soils of good moisture content. Infestations sufficient to cause widespread damage of this type are restricted to the areas north of Cardwell and one or two centres in the Herbert River district; south of Townsville, instances of such damage occur only at irregular intervals.

Several methods have been devised to assist in the control of this pest; in discussing these methods some consideration will also be given to certain measures which are more or less commonly practised and which are not considered to yield practical economic results.

Biological Control.—Little hope can be held out that the northern cane grub will eventually be controlled by the introduction of foreign insect parasites. Unlike small isolated islands such as the Hawaiian group the continent of Australia has a colossal number of native insect species. The northern cane grub is not an isolated member of its group, but is one of a number of closely-related grubs. True, these all have a number of natural parasites which attack them, but these parasites are, in turn, preyed upon by a vast array of hyperparasites. Consequently, even though there exist abroad parasites which will attack this grub it is highly probable that such would, upon introduction here, immediately receive the attention of a number of the native hyperparasites, and the importation be rendered abortive.

In June, 1935, 100 Giant American Toads were introduced from Hawaii (*see* Fig. 128). This toad has proved a very efficient agent in bringing about control of the white grub pest of sugar-cane in Puerto Rico, and was introduced in the hope that it might prove of similar utility here. The toad is thriving under North Queensland conditions and is multiplying rapidly, but it will be some time before its effects, if any, become apparent.

Collection and Trapping of Beetles.—The haphazard methods adopted in the past for the collection of beetles appear to be quite uneconomic and the continuance of such methods cannot be advocated. It has been the practice of certain Cane Pest Boards to pay prices ranging from 6d. to 1s. 6d. per pint for beetles collected by any person and delivered at certain points. The numbers of beetles so collected represent but a small proportion of the total beetle population, and even at the lowest price the cost of collection represents an outlay of about £5 10s. per 25,000 beetles. A 75 per cent. subsidy on the purchase of fumigant involves a Pest Board in an expenditure of approximately £4 10s. per acre, and assuming an average of five grubs per stool (it may be much more) the fumigation of an acre would bring about the death of about 25,000 potential beetles, as well as ensuring the complete protection of the existing crop. Finally, a fumigant subsidy system is not open to the abuses of beetle payment when it is impossible to identify the location of the collection of the beetles in all cases.

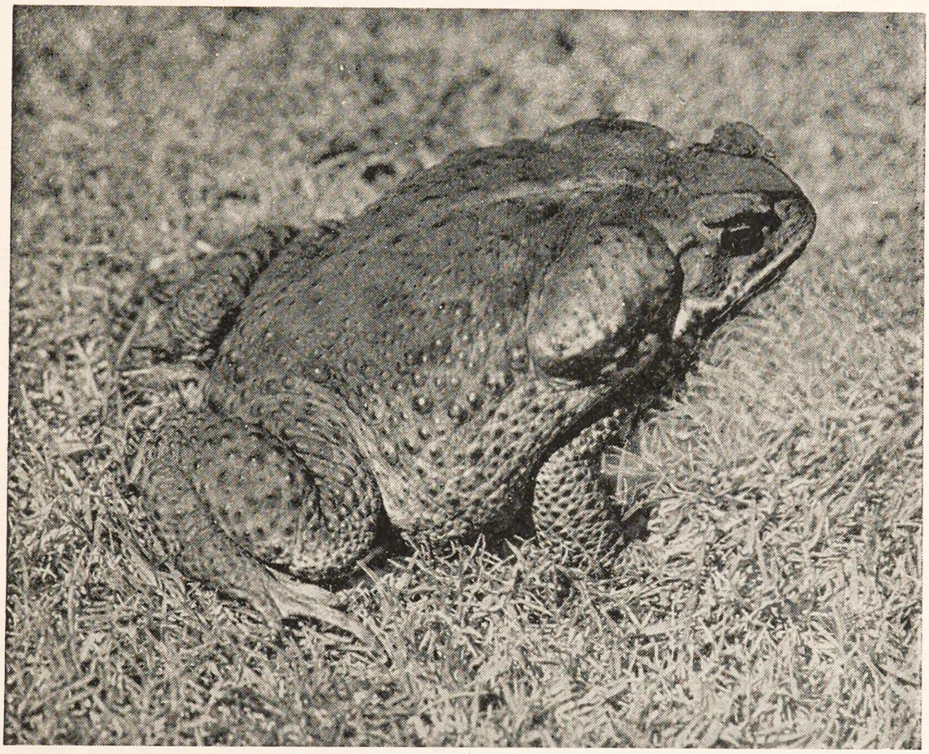


FIG. 128.—The Giant American Toad (*Bufo marinus*), ½ natural size.

Collection of Grubs.—For similar reasons as to costs and numbers of beetles collected, the collection of grubs cannot be advocated.

Elimination of Feeding Trees.—The mere cutting down of feeding trees in the surrounding uncultivated country has not been found to bring about any great improvement. However, where district-wide fumigation campaigns are conducted it may be found to be advantageous to cut down all feeding trees within the cane areas so as to drive the beetles to the outskirts of the district and then to concentrate fumigation within this zone.

Fumigation.—Fumigation is unquestionably the most efficient method at present available for the control of the northern cane grub and, when carried out properly, is practically 100 per cent. effective.

FIG. 129.—Soil fumigation of grub-infested sugar-cane with hand injector.

In order to find out whether fumigation is necessary a systematic digging out and mapping of each field should be carried out some seven to eight weeks after the main beetle flight. In every fourteenth row single stools should be selected at one chain intervals throughout these rows. Then, commencing from the centre of the interspace on either side of these selected stools and working inwards, the ground should be carefully turned over to spade depth and the number of

grubs per stool counted. If the numbers of grubs found are set out on a plan of the field then, knowing the number of grubs which is likely to cause damage on that particular type of soil, it can be decided whether all or part of the field should be fumigated. In fields which are regularly infested and any doubt exists as to whether fumigation should be carried out, a second digging should be made. For fumigation, a mixture of equal weights of carbon disulphide and paradichlorobenzene is recommended although, if it so happens that fumigation

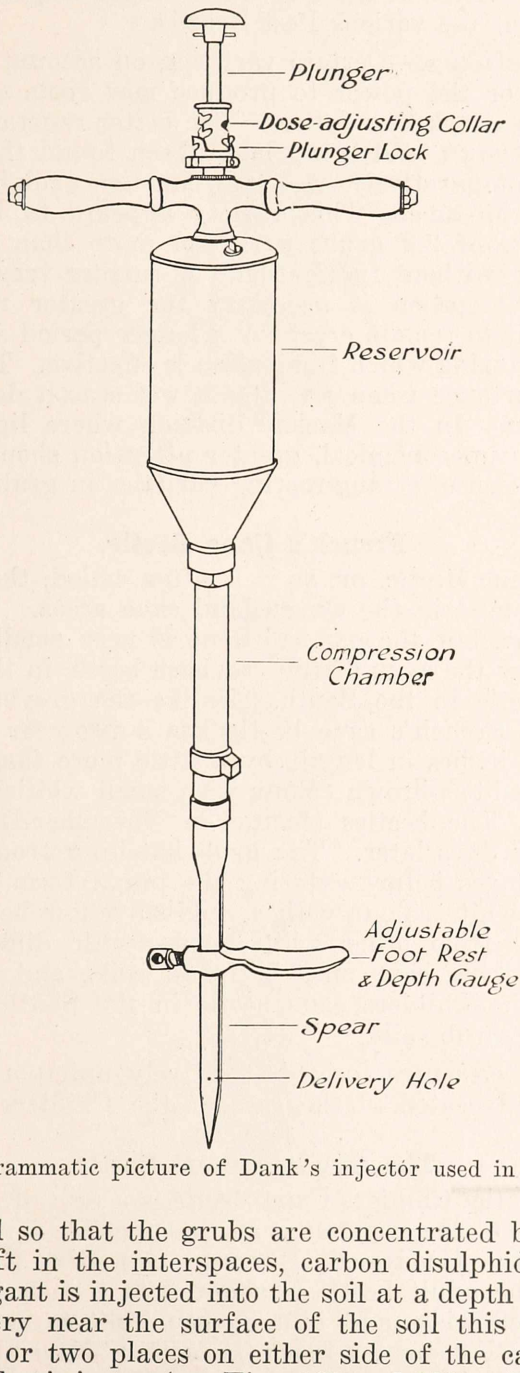


FIG. 130.—Diagrammatic picture of Dank's injector used in soil fumigation.

has been delayed so that the grubs are concentrated beneath the stool and none are left in the interspaces, carbon disulphide alone may be used. The fumigant is injected into the soil at a depth of 4 to $4\frac{1}{2}$ inches (if grubs are very near the surface of the soil this depth should be reduced) in one or two places on either side of the cane stool, with a "Danks" or similar injector (*see* Figs. 129 and 130). The injection hole

should then be carefully sealed by tramping on it. The amount of fumigant injected, which may be adjusted by a regulator, is generally about $4\frac{1}{2}$ cubic centimetres. Fumigation is useless unless carried out under conditions of favourable soil moisture; it should be done when the soil has just dried out sufficiently to permit of perfect working with implements.

Unless the farmer is familiar with fumigation methods his first attempts should be carried out under supervision, which will willingly be furnished by officers of the Bureau of Sugar Experiment Stations or the Supervisors of the various Pest Boards.

Resistant Varieties.—Certain varieties, on account of having strong rooting systems or the power to produce new roots quickly, are more resistant to grub attack than others. The better resistance of the variety D. 1135 is well known, and it has lately been found that the local seedling S.J.4 is comparatively resistant in the grub-infested areas of Hambledon and Mossman. This variety appears to be able to withstand an average of 2-3 grubs per stool more than either Badila or Clark's Seedling, without fumigation. A further very important point is that when fumigation is necessary the greater resistance of this variety enables it to remain erect for a longer period and so permits of a longer period during which fumigation is effective. This characteristic is of great importance when an intense wet season does not permit of early fumigation. In the Mackay district, where lighter crops often make fumigation uneconomical, greater attention should be paid to the possible substitution of strong-rooting varieties in grub-infested areas.

French's Cane Beetle.

French's Cane Beetle, or, as it is often called, the Frenchi Beetle, is widely distributed in the Queensland cane areas. The grub attacks the roots of cane, but the damage done is very small when compared with that done by the grub of the greyback beetle in the North, or even the Childers beetle in the South. Unlike the greyback, but like the Childers beetle, French's cane beetle has a two-year life cycle. This beetle is $\frac{7}{8}$ to $1\frac{1}{8}$ inches in length, by a little more than $\frac{1}{2}$ inch wide; it is a dull dark reddish-brown colour with small whitish scales scattered over the body. The beetles emerge in November-December and lay their eggs a few days later. The grub hatching from the eggs passes through three stages before entering the pupal form. The third-stage grub is a dirty white colour with a reddish-yellow head, and can only be distinguished from other white grubs with difficulty. However, it is found attacking cane only in forest soils, and so should not be confused with the Childers cane beetle in the South, since the latter is found only in scrub soils.

The control measures for this relatively unimportant pest are the same as those advocated in the case of the Childers cane beetle (*see* p. 181).

The Childers Cane Beetle.

The grub of the Childers Cane Beetle is a pest of sugar-cane chiefly in the scrub soils of the Isis, but is also responsible for a certain amount of damage in the Goodwood, Bingera, Gin Gin, Bucca, and Woongarra areas. The adult beetle is about $\frac{3}{4}$ to $\frac{7}{8}$ inch in length, a little more than $\frac{3}{8}$ inch wide, and is a glosssy light to reddish dark-brown colour. The beetles emerge from the soil in November or December, after the first soaking rains of that period of the year. After

Plate VI.

The Chief Insect Pests of Sugar-cane in Queensland.—(1) Grub of the Northern Cane Beetle; (2) French's Cane Beetle; (3) Childers Cane Beetle (male); (4) Northern Cane Beetle (female); (5) Grub stage of Beetle Borer; (6) Grub of French's Cane Beetle; (7) Grub of Childers Cane Beetle; (8) Cane Beetle Borer. All natural size except grub and beetle of the Beetle Borer (Nos. 5 and 6), which are twice natural size.

mating the females lay their eggs in the soil, often close to the spot from which they emerged, and so grubby patches tend to persist in the same fields year after year. The grubs which hatch from the eggs moult twice in the course of their life as grubs, thus giving three distinct stages of growth. Each of these stages is readily determined by the measurement of the head width, this being $\frac{1}{12}$, $\frac{1}{6}$, and $\frac{1}{4}$ inch for first, second, and third stage grubs respectively. In appearance the grub (which is shown in Plate VI.) is very similar to other white grubs and can only be distinguished by an expert; however, in Southern Queensland canefields it is usually the only grub present in any numbers in the scrub soils. The insect has a two-year life cycle; the three stages of the grub form last about 22 months, after which it pupates, the adult beetle emerging some two months later.

These grubs, particularly in the third stage, feed upon the roots of cane stools and deprive them of their normal supplies of water and plant foods, causing them to become yellow and stunted, or even to die out completely. This damage usually occurs in patches, giving very irregular stands of cane. Cane setts may also be destroyed before or soon after they germinate, rendering replanting necessary.

Soil fumigation with a mixture of paradichlorbenzene and carbon-disulphide (*see* p. 178 for method of application) is very effective in the control of this pest, but usually the expense involved does not permit of fumigation, except as a means of checking small new outbreaks, when it should definitely be employed. As far as possible ploughing should be carried out in the spring and summer months, when the grubs are located near the surface of the soil and are exposed by the plough; boys should then be employed to collect the grubs so exposed. When ploughing out old ratoons it is of considerable value to cover the ground with a rotary cultivator, which will chop up the stools and kill a large proportion of the grubs which lie near the soil surface. In the final ploughing the amount of grubs collected should be less than four quarts per acre, otherwise planting is unsafe. Spring planting should be avoided after a bad infestation of that particular field, as also should be the practice of ploughing out and replanting immediately afterwards. Old ratoons should not be grown, as they often act as centres from which the surrounding cane may become infested. Standover cane (unless it be the final crop) should be avoided, as the tall cane attracts the female beetles during the November-December flighting season. The best method of avoiding the attraction of egg-laden females is a bare fallow and so it is desirable to have cover crops ploughed in before November.

It should be noted that light traps are of no use as a control measure for this pest on account of the fact that the female beetles constitute only about one per cent. of the number caught.

CANE BORERS.

There are two types of borer attacking cane in Queensland, namely, the Beetle Borer and the Moth Borer. It is important that farmers should be able to distinguish between the two types since methods advocated for the control of the beetle borer may be quite useless against the moth borer and *vice versa.*

The Beetle Borer.

The beetle borer, also called the weevil borer, is common throughout the wetter sections of the cane belt, but is found as far south as Carmila, in the Mackay district. In the Mackay district, however, it is only a minor pest and does appreciable damage only to the softer varieties of cane in small localities; and, after a succession of wet seasons, the numbers of borers being reduced again with a return to normal climatic conditions.

The adult weevil or beetle is a small dark-brown insect about half-an-inch long with a curved beak-like head, and may readily be recognised after reference to Plate VI. It bores a short tunnel through the rind of the cane into the soft, juicy pith and lays its eggs at the bottom of the tunnel. The small creamy-white grub which hatches from the eggs has a reddish head and when fully developed is about ½ inch in length. It tunnels through the stalk, feeding on the soft pith, which it reduces to a condition resembling sawdust, and also allows the entry of the red rot fungus and other parasites which attack the remainder of the stalk. When ready to pupate the grub first bores a hole out through the rind and then retreats a little way back into the tunnel and surrounds itself with a peculiar cocoon made of cane fibres compactly interlaced. When mature, the weevil breaks out from the cocoon and makes its way out of the stalk through the hole previously bored; the whole cycle takes three to four months.

As stated above the damage caused by the borer consists in both a destruction of the juicy pith of the cane and the fact that its tunnelling allows the free entry of parasites which set up internal rots. Borers exhibit a pronounced preference for cane which is damaged in some way either by top rot, grubs, rat damage, flood damage, or any other injury which tends to bring about a souring of the cane. Standover cane is also much more frequently attacked than one-season-old cane.

A large measure of successful control has been obtained in Hawaii following the introduction of the Tachinid fly into that country. It should be borne in mind, however, that in that country there is a two-year cropping cycle so that there is always 50 per cent. of one-year old cane left standing to harbour the fly. With a system of annual cropping, such as rules in North Queensland, the period between harvesting and the growth of the new crop is a critical one for the Tachinid fly which is then decimated annually. Of perhaps more importance is the question of varietal susceptibility, our standard variey, Badila, being much more susceptible than the standard varieties of Hawaii. Under present conditions, therefore, it cannot be hoped that the Tachinid fly will in any way duplicate its success in Hawaii, and we are convinced that no good purpose would be served by breeding flies and making further liberations of them.

The incidence of borers in North Queensland has increased considerably during the past few years, particularly in the Johnstone district. Entomologists of the Bureau are now conducting a special investigation of the causes underlying this increase of the pest and methods which might be adopted for its control. It is yet impossible to make specific recommendations on the basis of the results obtained, but it is probable that field sanitation is an important factor.

The practice of harvesting cane "in the leaf" allows vast numbers of borers to escape from cane and tops left in the field, and to recommence breeding. In the early part of the harvesting season it is usual

to top the cane back in order to increase the c.c.s. value, and this discarded cane provides a very suitable place for the borers to lay their eggs. Under favourable conditions of moisture the eggs hatch out and the insect is able to complete its life cycle and beetles emerge before before the top dries out completely. When trash is conserved under moist conditions the blanket of trash naturally protects these tops from drying out and so increases the chances of the young borers' survival. Where the trash is conserved and the tops left undisturbed they dry out quickly but where they are raked into heaps and allowed to rot the closer packing helps to retain moisture and the young borers (many of which survive the moderate heat of a trash fire) can reach maturity. Under the conditions outlined above the young ratoon cane may commence its growth with an infestation of thousands of borers per acre. Both ratoons and plant cane are, of course, exposed to the migration which results when an adjoining field is harvested. The planting of borer-infested cane also ensures the early infestation of plant crops, and in this connection it should be noted that if cuttings are left exposed, before planting, in the vicinity of borer-infested fields, large numbers of eggs are likely to be laid in the cut ends.

It would appear, therefore, that the best methods of borer control immediately available lie in plant selection and pre-harvest burning and/or the ensuring that the burnt tops are not raked into heaps and left to rot. Naturally, pre-harvest burning or burning of trash cannot be unreservedly recommended, since there are other economic factors to be considered, such as the deterioration of burnt cane and the necessity for combating soil erosion and exhaustion. The desirability of the practice must be determined according to circumstances; it is obvious, however, that isolated attempts to effect control in this manner would be largely nullified, and it could only be utilised to best advantage on a district-wide basis.

Hardness of rind definitely confers resistance to borer attack, and all new varieties are now tested with a rind-hardness machine to determine whether they are likely to be sufficiently resistant to be planted commercially. The breeding of canes with a harder rind is a promising line of attack, and hard-rinded varieties, such as S.J. 4, D. 1135 and Q. 2, are much more resistant than Badila and Clark's Seedling. Experiments in early trashing have also been carried out and, though this practice decreases borer attack, it is doubtful if it is economic where labour has to be employed.

Moth Borers.

Cane is attacked by several types of moth borer in Queensland, but the most important of these is the so-called Large Moth Borer. The latter is a light-yellow to silver-brown moth which in the caterpillar stage is light-purplish in colour and approximately an inch in length when full grown. The caterpillars eat their way into the young, tender centres of cane shoots (both plant and ratoon), causing the shoots to die. These "dead hearts" may be very conspicuous in a field of young cane and give the impression that a considerable amount of damage is being done. In most cases, however, the losses are so small as to be practically negligible. Even in the absence of any pests and diseases, up to 60 per cent. of the shoots produced in a field die without forming cane, due to over-crowding. Consequently, in the majority of cases the moth borer merely accelerates a thinning out which would take place in any case, and the infestation is rarely sufficient to produce a weak stand of cane.

The caterpillar will also bore into standing cane, on occasions, but such attacks are usually confined to the headlands.

In spite, perhaps, of appearances to the contrary, this pest is rarely responsible for material damage and control measures are rarely necessary. The growth of grass and weeds on headlands and in the fields encourages these insects, and clean cultivation is advocated but is not always a specific remedy since the borers may migrate in from adjoining grass lands.

WIREWORMS.

The term "wireworm" is commonly used to describe the larvæ of the "crack-a-jacks" or "click beetles." Several types of wireworm are found in canefields throughout this State, but serious damage as a result of the attack of this pest is practically confined to parts of the Mackay and Proserpine mill areas. The activities of these pests, resulting in bad strikes, have been much more pronounced during the past fifteen years when, due to the great extension of the sugar industry, considerable areas of low, badly-drained land have been brought under cultivation.

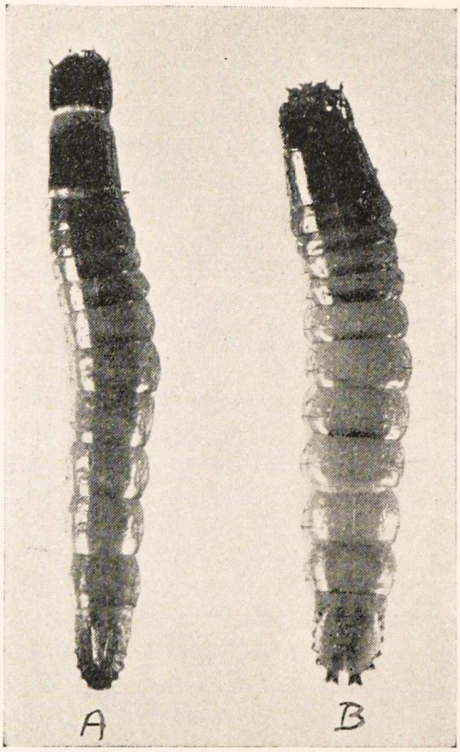


FIG. 131.—Full-grown wireworms from canefields, four times natural size. "B" (*Lacon variabilis*) is the wireworm responsible for most of the damage in the lowlying areas of the Mackay district.

Investigation has shown that for all present practical purposes only one particular wireworm requires the application of control measures in these districts, and only this "lowland" type is discussed here.

The adult is a small dark-brown beetle about ½ inch long, but owing to its secluded habits it is rarely seen unless a special search is made; its natural home is low, swampy grasslands, but it has gradually

migrated into badly-drained canefields. The adults appear chiefly in November and December, and about three to four weeks later the females deposit their eggs in the soil. After a further eight days the young worms hatch out and they pass through eight distinct stages before pupation, which takes place in October-December. The fully-developed final stage wireworm is a pale-yellow semi-flattened worm with a brown head and a brownish end segment; the segments are clearly marked, and the length is about $\frac{3}{4}$ to $\frac{7}{8}$ inch (*see* Fig. 131). In the first two or three stages of its life (that is, during January-February) the young wireworm requires extremely wet soil conditions in order to survive, but in later stages it can withstand very dry soil conditions. These facts are of the greatest importance in effecting control of this pest.

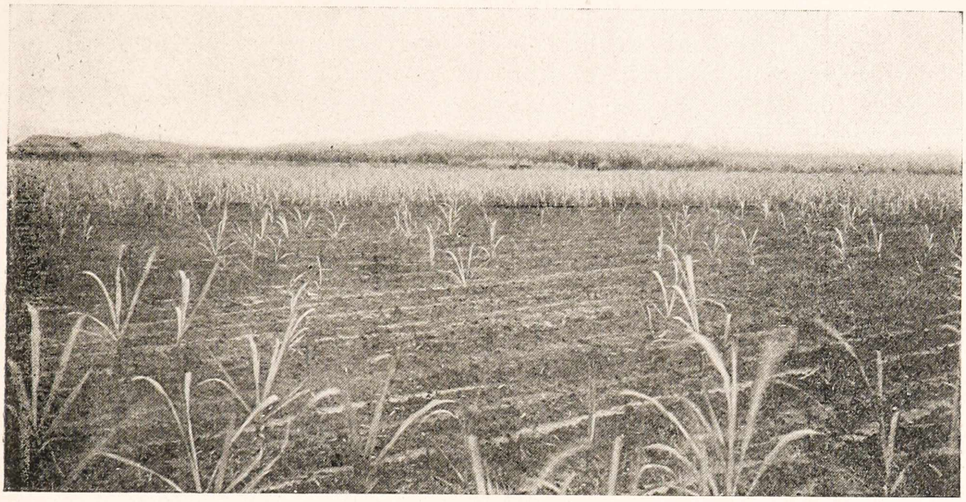


FIG. 132.—A poor stand of cane in a badly drained depression due to the eyes of setts having been destroyed by wireworms.

Wireworms damage cane chiefly by boring into and eating the central portion of the swollen buds of the newly-planted cane setts or the central portion of very young shoots, thus preventing germination. Such damage usually occurs in patches of low, badly-drained land (*see* Fig. 132), and under these conditions it has been no uncommon experience for farmers to be forced to replant the patches as many as three times before obtaining a satisfactory strike. Sometimes wireworms will eat into the underground portions of larger shoots, thus causing "dead hearts" similar to those caused by the moth borer (*see* p. 183). In the case of the wireworm, however, only a small hole is bored across the centre of the shoot, while the moth borer usually eats out the centre of the shoot for some distance above or below the hole by which it has entered.

Numerous methods have been advocated at various times for the control of this pest, but as a result of intensive investigation only one method has been found satisfactory in the abovementioned districts, namely—the provision of suitable drainage. Collection of wireworms, the use of poison baits, growing of green manure crops, fallowing, deep ploughing, clean cultivation, and the use of artificial fertilizers are some of the methods which have been investigated and found to have no value in this respect. In particular it should be stated that the often-advocated application of superphosphate is quite without value in the control of this pest.

Since the majority of wireworms have finished feeding by August-September, plantings made after this date may often escape damage in known bad wireworm patches. Such late planting is not only undesirable from the agricultural point of view, but often impracticable in these dry areas. Moreover, if a field of ten acres has a wireworm patch one acre in extent, then it is obviously bad practice to delay planting in nine acres until a satisfactory strike is obtainable in the tenth acre.

It has been stated previously that in its early stages the wireworm requires extremely moist conditions for its survival, and such conditions are only provided by excess water. It has been definitely proved by numerous field trials that wireworm damage can be prevented by preventing the collection of water in these patches. The land should be bedded up and drains cut so as to give permanent drainage from all parts of low-lying fields subject to wireworm attack. This prevents the accumulation of surface water during the period of heavy rainfall, and moisture conditions are so adjusted as to prevent the survival of the wireworms in their early stages. It must be emphasised, however, that such drainage must be completed before December-February, and it is for this reason that the common practice of bedding up and cutting drains just prior to planting is quite ineffective in wireworm control. In addition to controlling wireworms and eliminating the necessity for replanting affected patches, this practice is highly desirable from the standpoint of good agricultural practice.

Other types of wireworm may be found in well-drained fields, especially after grass fallow. These, however, do little damage, and require no control measures; bad strikes in well-drained fields are often attributed to these wireworms but careful investigation will invariably show that the failure of the plants is due to some other cause.

FIG. 133.—Army worm attack on Badila plant cane. Note amount of dead grass in interspaces; this block was allowed to get very dirty and weedy.

ARMY WORMS.

Army worms are dull greenish-brown caterpillars which are frequently found in fields of young cane during the spring and which, on occasion, may invade the fields in vast hordes or "armies." These caterpillars attack the leaves of cane, eating out large irregular pieces of the leaf blade, and when the attack is severe the plants may be entirely stripped of their green foliage. Since this attack is directed at the young plant and ratoon cane, it follows that the crop may receive a considerable set-back. The typical appearance of young cane plants which are being attacked by army worms is illustrated in Fig. 133. The fully-grown caterpillar is about 1½ inches in length.

Most cane farmers will have observed that the outbreaks usually originate in grass land or in grassy fallow blocks within the farm. The caterpillars appear to prefer to feed upon the natural grasses or small young crops of the "grassy" fodder crops. Leguminous crops seem to attract them but little, and it is a common sight to see them proceeding through lucerne and green manure crops but eating only the grass which happens to be present. In so far as sugar-cane is concerned, damage to this plant by army worms is usually restricted to small cane, particularly ratoon cane, which is attacked in the spring months. Grown crops are rarely attacked to any appreciable extent, and consequently there is little likelihood of cane being severely attacked during February and March, when outbreaks sometimes occur.

Fortunately these army worms are attacked by many parasites which soon gain the upper hand when weather conditions are favourable. Consequently, since the first outbreak in sugar districts is usually confined to grass lands the caterpillars are, as a rule, overcome before they can make serious inroads into cane fields. In the dryer spring months, particularly in Southern Queensland cane areas, the army worm may keep ahead of its parasites for some time and it may appear desirable to adopt the control measures as set out below to protect the young plant and ratoon crops.

If the advancing army of caterpillars has not yet entered the cane-field, or has only just gained entry, its advance may be stopped by ploughing a deep furrow with the vertical face nearest to the crop to be protected. Deeper pits are then dug in the furrow at intervals of about 20 feet. The advancing army worms then crawl into the furrow and, being unable to scale the vertical wall, they move along the furrow and eventually fall into the pits, where they may be killed. Another method is to spray all vegetation, in a strip one chain wide, in front of the army worms, with arsenate of lead solution (5 lb. to 100 gallons of water). The burning of cane trash also helps to keep them under control, but this is not advisable where trash conservation yields good results.

Where army worms are already established in a field of cane, the best method of destroying them is by the use of poison bait as follows:—

Composition of bait:—

Bran	25 lb.
Paris Green or White Arsenic ..	1 lb.
Molasses	2 quarts
Water	2 gallons (approx.)

The juice of six lemons or oranges.

The Paris Green or White Arsenic is thoroughly mixed with the dry bran so as to get some of the poison in contact with each particle of bran. The lemon juice, together with the molasses, is mixed with some of the water and this mixture is then poured over the poisoned bran and the whole mixed thoroughly. The remainder of the water is then added, a little at a time, until the bait is moist enough to adhere to the fingers but will not run through them. The bait is lightly and evenly distributed along the infested cane rows in the late afternoon, about 15 to 20 lb. of this mixture being sufficient to bait an acre. The army worms feed on the bait during the night, and in a few days scarcely a single live caterpillar should remain.

TERMITES.

Termites, commonly but incorrectly known as "white ants," are sometimes a source of trouble to canegrowers. Although a number of the smaller types of termite sometimes destroy setts in the ground, and on rare occasions growing stools, the so-called Giant Termite, is the only termite of real economic importance. Fortunately, this giant termite is a pest of cane only in the Burdekin district, but in certain localities, particularly on the fringe of the forest, it may destroy fairly large patches of standing cane. The termites bore into the base of the stalk and rapidly eat out the central flesh of the stalk, leaving the rind intact. The fibres in the rind suffice to keep the leaves supplied with water and so the presence of the pests is usually not noticed until they eat right up to the growing point. "Dead hearts" then appear, and on shaking such a stalk it is found to be weightless, and on cutting and splitting it is found to be hollow throughout its whole length.

The adult members of a colony of termites are divided into workers, soldiers, and winged forms with, usually, one queen; the worker is creamy-white in colour and about ½ inch long. The giant termite does not build a mound and the nest can only be found with difficulty as the termites proceed to the logs, trees, &c., which they attack, not above ground but through tunnels which may be upwards of 100 yards in length. The main nest often extends several feet underground.

The smaller types of termite can be controlled by treating the nests with carbondisulphide or by laying baits of pine treated with molasses and arsenic. In the case of the giant termite, however, the nests are not easily discovered and arsenic, although widely used, is not so effective. Infested trees, logs, &c., should be destroyed and molasses and arsenic baits used to protect fence posts. If a small patch of cane near a headland is attacked it is often advantageous to plough a short furrow along the headland, sprinkle a bait consisting of bran or sawdust mixed with molasses and arsenic along the bottom of the furrow, and then cover the furrow over again.

Termites attack cane chiefly for the moisture obtained from it, but, nevertheless, they dislike very wet conditions. Consequently, where irrigation is practised frequent waterings in the vicinity of the attack will greatly reduce the damage. For the same reason, planting in spots liable to attack should not be carried out in dry weather unless the ground is well watered.

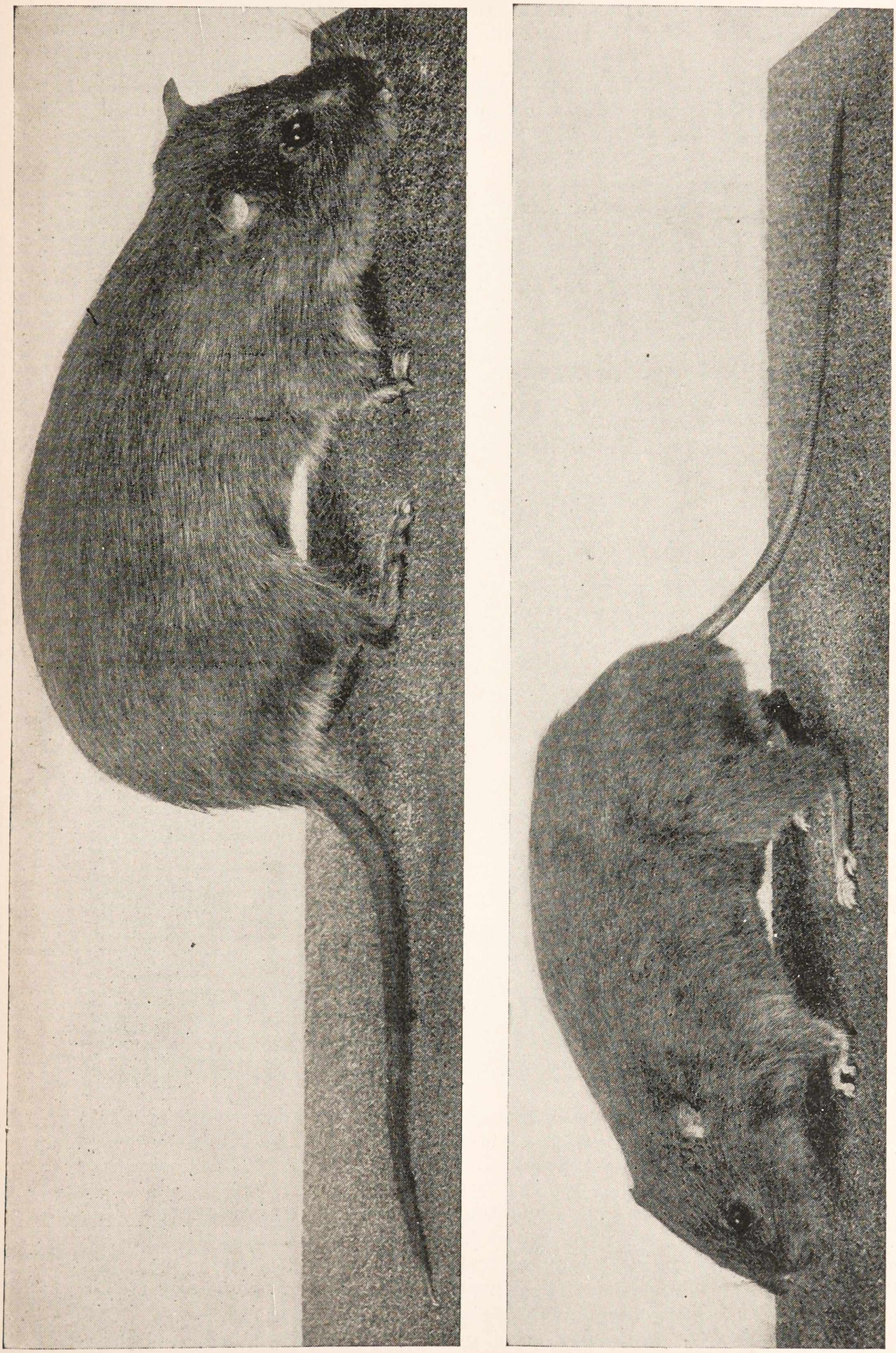


FIG. 134.—The two species of rat chiefly responsible for damage to cane in Queensland canefields:—
Upper.—*Rattus conatus* or the "field" rat ($\frac{3}{4}$ natural size).
Lower.—*Melomys littoralis* or the "khaki" rat ($\frac{4}{5}$ natural size).

RATS.

Rat damage is found to a greater or less degree throughout the whole of the cane belt and serious damage periodically occurs in parts of the large area north of Townsville and in certain localities in the Mackay district. Rat populations and degree of damage fluctuate greatly according to season; these pests last assumed very considerable importance in North Queensland in the years 1934 and 1935 but declined with less favourable conditions in 1936 and the following years.

FIG 135.—Stalks of Badila cane damaged by rats. Note that in this case the proportion of cane actually eaten is small, the chief loss being indirect through collapse and death of stalks.

Practically the whole of the damage is caused by two species of rat, both native to Australia, namely, the so-called field rat (*Rattus conatus*) and the smaller "Khaki" rat (*Melomys littoralis*) (*see* Fig. 134). The former burrows in the ground while *Melomys* usually nests in grass, cane, and low-growing "shrubs" amongst cover. Rats commence seriously damaging cane usually about June and damage

increases in intensity until about October when it commences to decline. They gnaw through the internode, causing the stalk to collapse (Fig. 135); at times a very high proportion of the stalks may be lost in this way (*see* Fig. 136).

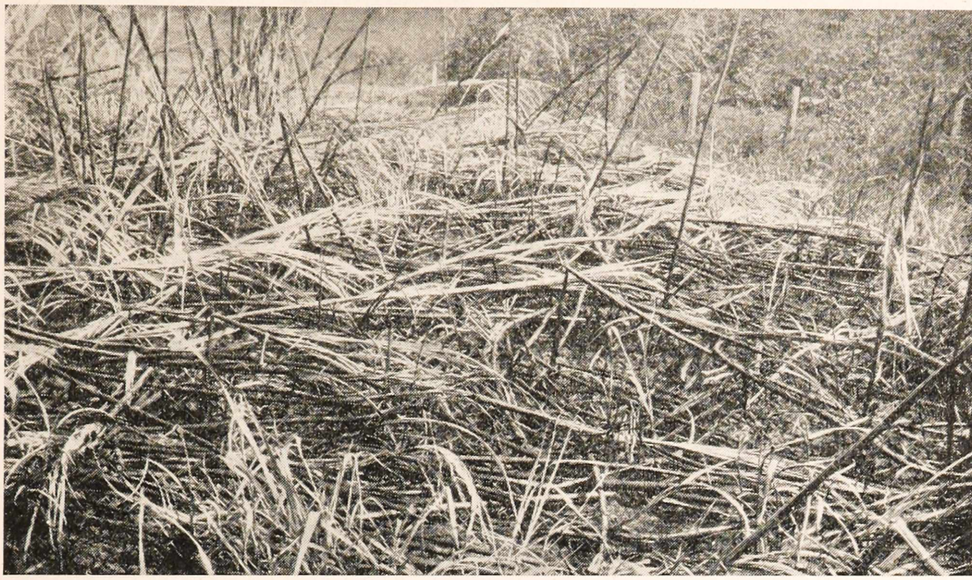


FIG. 136.—A field of the variety P.O.J. 213 in which 98.5 per cent. of stalks were damaged by rats; photo. taken after burning of field.

Two forms of control measure, mostly used in conjunction, have been adopted in Queensland—destruction of harbourage and the laying of poison baits. Destruction of harbourage is a highly important factor in the control of these pests and every effort should be made to keep headlands clean and to fence and graze off adjacent land, gullies, and creeks. Flame throwers have been used in the destruction of harbourage, but this method is too expensive for general use except in small areas which cannot be grazed and cannot be attacked with implements. The laying of poison baits in Queensland canefields is often done in the form of a series of district-wide campaigns organised by Cane Pests Boards, which supply baits and supervision. Some baiting is done immediately following harvesting, but campaigns are generally carried out during the wet season, prior to the commencement of damage to cane. At this time the baits used consist almost exclusively of wheat treated with thallium sulphate, a strength of about 1/300 being commonly used. The size of individual baits varies from $\frac{1}{5}$ to $\frac{1}{3}$ oz., the grain being wrapped in small weatherproof packages. Sometimes the poisoned grain is lightly sprayed with linseed oil before packeting to increase its attractiveness. Baits of this type, ready for distribution, are now obtainable from several commercial firms. The baits are laid along headlands, in adjoining gullies and creeks, and in cane when rats are present there. The number of baits laid per acre varies considerably, and reaches as high as 600. During the dry season baits consisting of small pieces of fresh bread spread with a prepared phosphorus paste are also used. The cheapness of this form of bait permits heavy baiting, but it should be borne in mind that baits should be fresh and in the field they lose their effectiveness after an exposure of about 48 hours.

Poison campaigns have been reported from some countries as giving a satisfactory degree of control of a rat problem, whilst in others the control of rats in fields has not been satisfactorily effected. The method is still on trial in Australia, but until more is known of the conditions governing reproduction in rats and the effects of climatic variation on rat populations it is difficult to judge, with any degree of confidence, the efficiency of the campaigns conducted in the past.

Investigations so far conducted by the Bureau in the Mackay district suggest that the best protective results are obtained by baiting a field with this bait at the time when rats commence to cause appreciable damage in it. This practice aims at the protection of the particular field and does not aim at the reduction of the rat population as a whole as do the wet season campaigns.

Baiting for the protection of a particular field must be considered to be analogous to fumigation in the case of cane grubs, but its success appears to depend considerably on the stage of development of the rats in that field. The opinion at present held by Bureau officers is that the general poisoning campaigns are uneconomic and exercise no lasting effect on rat populations.

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